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Volume I. Addition to the Liquid Stream

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Volume I: Addition to the Liquid Stream

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16. ABSTRACT

The report provides information needed to facilitate septage disposal at municipal wastewater treatment plants. Research assessed the effects of septage addition to primary and secondary biological waste treatment processes. Septage was added to an extended aeration process, a two-stage conventional activated sludge process, and a pilot plant operated both as an extended aeration and a conventional activated sludge facility

All processes were monitored during a no-septage feed baseline period, which was followed by constant feed and slug feed. Results included process loading for existing plants, design criteria for new facilities and cost of treatment of septage. Experience gained in feeding and treating large quantities of septage is reported.

Septage is readily treated biologically with domestic sewage. The organic and solids content of septage averages about 50 times that of domestic sewage. Solids removal in primary clarification is excellent and in combination with primary or secondary sludge, septage dewaters well.

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MONITORING SEPTAGE ADDITION TO WASTEWATER TREATMENT PLANTS

Volume I: Addition to the Liquid Stream

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FOREWORD

The U. S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report assesses the effects of septage addition to municipal wastewater treatment plants. It provides treatment costs and guidelines for designing receiving facilities and treatment works for combined septage and sewage treatment.

Francis T. Mayo
Director
Municipal Environmental Research
Laboratory

ABSTRACT

The report provides information needed to facilitate septage disposal at municipal wastewater treatment plants. Research assessed the effects of septage addition to primary and secondary biological waste treatment processes. Septage was added to an extended aeration process at Medfield, Massachusetts, to a two-stage conventional activated sludge process at Marlborough, Massachusetts, and to a University of Lowell pilot plant, operated both as an extended aeration and a conventional activated sludge facility.

A three phase monitoring program was conducted at each plant. All processes were monitored during a no-septage-feed baseline period, which was followed by constant feed and slug loading periods.

Research results included acceptable process loading for existing plants, design criteria for new facilities, the cost of treating septage and regulations for controlling disposal. Experience gained in feeding and treating large quantities of septage is reported.

Septage is readily treated biologically with domestic sewage. The organic and solids content of septage averages about 50 times that of domestic sewage. Solids removal in primary clarification is excellent and in combination with primary or secondary sludge, septage dewaters well.

This report was submitted by the University of Lowell in fulfillment of Research Grant No. R805406010, under the sponsorship of the U. S. Environmental Protection Agency and under Grant No. 76-19 under the sponsorship of the Massachusetts Division of Water Pollution Control. This report covers the period August 25, 1977, to November 24, 1978.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

AS --activated sludge
AWT --advanced waste treatment
BOD$_5$ --five day biochemical oxygen demand
BOD$_L$ --ultimate biochemical oxygen demand
C --composite sample
cm --centimeter
COD --chemical oxygen demand
CST --capillary suction time
cu ft --cubic feet
cu m --cubic meter
D --daily
D.O. --dissolved oxygen
EA --extended aeration
F/M --food to microorganism ratio
g --gram
G --grab sample
gal --gallon
hp-h --horsepower-hour
hr --hour
kg --kilogram
km --kilometer
kw-h --kilowatt hour
l --liter
LAS --linear alkyl sulfonate
lbs --pounds
mgd --million gallons per day
mg/l --milligrams per liter
mi --mile
ml --milliliter
MLSS --mixed liquor suspended solids
MLVSS --mixed liquor volatile suspended solids
ORP --oxidation reduction potential
PRI --primary plant
rpm --revolutions per minute
s --standard deviation
sec --second
SEC --secondary plant
SF --sand filter
sq ft --square feet
sq m --square meter

ABBREVIATIONS AND SYMBOLS (CONT'D)

ABBREVIATIONS

SRT	--solids retention time
SS	--suspended solids
susp	--suspended
SW	--semi weekly
TF	--trickling filter
TKN	--total kjeldahl nitrogen
TSS	--total suspended solids
Vol	--volatile
VOL	--volume
VSS	--volatile suspended solids
$\bar{x}$	--mean of readings
yr	--year

SYMBOLS

Al	--aluminum ion
Al_2O_3	--aluminum oxide
ΔBOD	--difference in BOD_5 input between Phases 1 and 2
C	--carbon, dissolved oxygen concentration, or cost
^{o}C	--degrees centigrade
$CaCO_3$	--calcium carbonate
Cd	--cadmium
Cr	--chromium
C_s	--saturation dissolved oxygen concentration
Cu	--copper
$C_5H_7NO_2$	--empirical formula for cell tissue
H	--diversity index
HCO_3	--bicarbonate ion
H_2CO_3	--carbonic acid
H_2O	--water
K	--oxygen transfer coefficient
K_d	--endogenous decay coefficient
K_{O_2}	--half saturation constant for oxygen
n	--total number of organisms
n_i	--number of organisms in the i^{th} species
N	--nitrogen
NH_3-N	--ammonia nitrogen
NH_4	--ammoniom ion
Ni	--nickel
NO_3	--nitrate ion
NO_3-N	--nitrate nitrogen
O_2	--oxygen
P	--phosphorus
Pb	--lead

ABBREVIATIONS AND SYMBOLS (CONT'D)

SYMBOLS

Q --flow rate
Qr --recycle flow rate
U --food to microorganism ratio
v --cost per cu m (1000 gal) liquid
w --cost per kg (lb) BOD
x --cost per kg (lb) COD
y --cost per kg (lb) suspended solids
Y --actual cell yield coefficient
Y_{obs} --observed cell yield coefficient
z --cost per kg (lb) phosphorus
Zn --zinc
Θ_c --mean cell residence time
μ --micron
μ_N --nitrosomonas growth rate
$\hat{\mu}_N$ --peak nitrosomonas growth rate

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SECTION 1

INTRODUCTION

SEPTAGE - AN OVERVIEW OF THE PROBLEM

At the inception of this project a cross-section of waste water treatment plant operators in the Commonwealth of Massachusetts were asked if they had experience treating septic tank wastes or septage. Many indicated that they had difficulties treating this waste; many accepted only small quantities of septage and some were reluctant to treat it at all. These operators were justifiably concerned about process upset or about violating regulatory requirements for effluent quality. They expressed a need for information upon which to base a reasonable estimate of the incremental cost of treating septage.

At relatively small treatment plants a 4 to 12 cu m (1,000 to 3,000 gal) truckload of concentrated waste, discharged in a period of minutes, can represent a significant load on the plant, depressing oxygen levels. Plants designed for comparatively consistent sewage solids and organic concentrations and the normal diurnal fluctuations in sewage flow can have difficulty if subjected to slug loadings of septage in which organic and solids concentrations can be two orders of magnitude greater than the concentration found in sewage. In the past, operators and local community governments have exercised minimal control over haulers' schedules and the origin of collected wastes. Regulating an occasional load of restaurant septage with high grease content or a potentially toxic industrial load is difficult at plants which do not exercise tight controls on incoming trucks.

In contrast to the experience at small plants, large treatment plants experience little difficulty in handling septage. Primary clarifiers and large volume aeration tanks at these plants attenuate the impact of slug loading. In addition, septage volume has been a minor fraction of their sewage flow. Few plants in Massachusetts now receive more than 0.5% of their design sewage flow capacity, and most plants treat considerably less.

Plants that now treat septage in Massachusetts are shown on Table 1.

TABLE 1. LISTS OF PLANTS TREATING SEPTAGE IN MASSACHUSETTS

Plant location	Type of process	** Design flow cu m/sec	(mgd)	Average daily flow cu m/sec	(mgd)	Percent septage/ sewage
Amherst	AWT	0.15	(3.5)	0.31	(7)	0.22
Barnstable	PRI	0.06	(1.4)	0.07	(1.5)	1.79
Boston-Deer Is.	PRI	15.03	(343)			unknown*
Boston-Nut Is.	PRI	4.91	(112)			unknown*
Brockton	AS	0.53	(12)	0.44	(10)	0.15
Chicopee	PRI	0.53	(12)	0.31	(7)	0.14
Fall River	PRI	1.10	(25)	0.66	(15)	0.22
Fitchburg West	AWT	0.54	(12.4)	0.44	(10)	0.10
Franklin	TF	0.07	(1.5)	0.08	(1.8)	0.27
Gardner	TF	0.17	(3.8)	0.09	(2)	0.01
Greenfield	TF	0.14	(3.2)	0.14	(3.2)	0.13
Haverhill	AS	0.79	(18)	0.53	(12)	0.03
Ipswich	EA	0.08	(1.8)	0.04	(0.8)	0.50
Lawrence	AS	2.28	(52)	1.31	(30)	0.04
Leominster	AS	0.22	(5)	0.26	(6)	0.01
Manchester	EA	0.03	(0.6)	0.01	(0.3)	0.30
Marlborough East	AS	0.24	(5.5)	0.11	(2.5)	0.16
Marshfield	SEC					
Medfield	EA & SF	0.07	(1.5)	0.01	(0.3)	0.40
Middleboro	TF	0.04	(0.8)	0.05	(1.1)	0.73
Milford	TF	0.18	(4)	0.11	(2.5)	0.04
Mills	EA & SF	0.01	(0.3)	0.01	(0.3)	0.07
Newburyport	PRI	0.11	(2.6)	0.11	(2.5)	unknown*
Northampton	PRI	0.13	(3)	0.15	(3.5)	0.17
Pittsfield	TF	0.48	(11)	0.39	(9)	0.07

(continued)

TABLE 1. (continued)

Plant location	Type of process**	Design flow cu m/sec	(mgd)	Average daily flow cu m/sec	(mgd)	Percent septage/ sewage
Plymouth	EA	0.08	(1.8)	0.13	(3)	0.67
Rockland	AS	0.04	(1.0)	0.04	(0.9)	0.50
Rockport	EA	0.07	(1.6)	0.04	(1.0)	0.80
Scituate	EA	0.04	(1.0)	0.01	(0.3)	1.00
Shrewsbury	TF	0.08	(1.8)	0.05	(1.2)	0.33
Southbridge	EA	0.10	(2.3)	0.09	(2)	0.10
Springfield	PRI	1.31	(30)	0.96	(22)	0.09
Sunderland	EA	0.02	(0.5)	0.01	(0.2)	0.67
Taunton	AWT	0.44	(10)	0.26	(6)	0.40
Webster	EA	0.28	(6.3)	0.15	(3.5)	0.23
Westborough	EA	0.05	(1.1)	0.04	(1.0)	0.15
Westfield	AS	0.18	(4)	0.18	(4)	0.35
Worcester	AS	2.45	(56)	1.53	(35)	unknown*

* Septage discharged directly into sewer system

** Type of treatment category

PRI - Primary wastewater treatment
AS - Conventional activated sludge
EA - Extended aeration
SEC - Secondary biological treatment
TF - Trickling filter
AWT - Advanced wastewater treatment
SF - Sand filter

The list was compiled from telephone surveys conducted in the spring of 1977 and in July 1978 and from engineering consultant studies.[1&2] An effort was made to include all plants now treating septage. The list shows the present low percentage input to plants, and indicates that only a small number of the more than 144 plants in Massachusetts treat septage.

There is an obvious need to facilitate septage treatment where homes served by septic tank disposal systems are within an economical hauling distance of wastewater treatment plants: 16 km (10 mi) is considered to be a reasonable distance, 32 km (20 mi) excessive. Acceptance can be encouraged by providing treatment plants with facilities to receive and process domestic septage, as well as commercial and industrial septage. It can also be encouraged by establishing process loading guidelines, determining alternative ways of treating septage, by devising methods of monitoring septage characteristics, and controlling the rate and strength of septage input to plants.

Above all, communities need a basis for establishing handling and treatment charges. The widespread septage pollution of land and water that now occurs can be greatly reduced if sewered communities with treatment plants will accept septage from adjacent non-sewered communities. Bases are needed to establish equitable charges. Regulations are needed to facilitate plant use, where applicable, and to discourage contamination of our environment.

THE SCOPE OF THIS RESEARCH

This research provides information needed to facilitate the treatment of septage at municipal treatment plants. It assesses the effects of septage addition to full and pilot scale plants, including the impact of various loading methods and loading levels on unit process performance and effluent quality. Operating procedures, difficulties and costs are examined. Guidelines are recommended for septage loading rates, plant operation control strategies, designing septage receiving and handling facilities, and regulatory procedures for septage disposal.

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[1] Whitman and Howard, Inc., "A Study of Waste and Septic Tank Sludge Disposal in Massachusetts", a report for Massachusetts DEQE, December, 1976.

[2] U.S. EPA, "Municipal Wastewater Treatment Facilities in New England", Region 1, July 1977.

SEPTAGE CHARACTERISTICS AND QUANTITIES

In 1977, EPA reported over seventeen million on-site wastewater disposal systems in use, nearly 25 percent of all households in the United States. These systems predominate in suburban and rural areas of New England, the Pacific Northwest, and in some southeastern states. Estimates of the total quantity of septage pumped yearly, based upon average tank pumping frequency, or treatment plant and pumper surveys, reveal the magnitude of this regional problem. It is obvious that immense quantities of septage are generated yearly and that a high percentage of this potentially hazardous waste is discharged directly to the environment.

Septage consists of the mat of grease and scum on the surface of septic tanks, the accumulated sludge at the bottom of tanks and the sewage present at the time of pumping. Organic solids and nutrient concentration are a function of the relative proportion of sludge and supernatant. The fraction of each component is determined by the interval between pumping and the quantity and characteristics of the waste discharged. Septage solids and organic concentrations can vary over three orders of magnitude. Commercial and industrial septage, that is typically hauled with domestic septage, increases this variability, and may contribute particular contaminants in concentration sufficient to inhibit or upset biological processes. Quality characteristic variability has often been stressed in literature dealing with septage; but for practical purposes, variability at municipal plants is significant only when viewed in terms of the holding capacity at inlet works and the size of plant processes, both of which tend to attenuate the effects of a single concentrated load.

During the course of this study, approximately 2,160 cu m (570,000 gals) of septage were added to the treatment plants. Septage was analyzed throughout the study. Samples were collected from individual trucks and from storage tanks containing up to 254 cu m (67,000 gals) of the waste. Table 2 shows an estimate of average concentration based upon the results of all analyses. These estimates are compared in Table 2 with values published by EPA. Other estimates are readily available.[3&4]

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[3] I. A. Cooper and J. W. Rezek, "Septage Treatment and Disposal", prepared for U.S. EPA, 1977.

[4] A. J. Condren, "Pilot Scale Evaluations of Septage Treatment Alternatives", U. S. EPA, EPA-600/2-78-164, September 1978.

TABLE 2. SEPTAGE CHARACTERISTICS (mg/l)

	Average values this study	EPA average concentration
Total Solids	11,600	38,800
Total Volatile Solids	8,170	25,260
Total Suspended Solids	9,500	13,000
Volatile Susp. Solids	7,650	8,720
BOD_5	5,890	5,000
COD	19,500	42,850
Total Organic Carbon		9,930
Total Kjeldahl-N	410	677
Ammonia-N	100	157
Total Phosphorus	190	253
Alkalinity, $CaCO_3$	610	
Grease	3,850	9,090
pH	6.5	6.9
LAS		157
Metals		
Aluminum		48
Arsenic		0.16
Cadmium	0.1	0.71
Chromium	0.6	1.07
Copper	87	6.4
Iron		205
Mercury		0.28
Manganese		5.02
Nickel	0.4	0.9
Lead	2	8.4
Selenium		0.076
Zinc	9.7	49

In many respects, septage is a waste similar in characteristics to sewage, but more highly concentrated. Due to these similar characteristics, the effects of septage upon a plant are predictable. For example, design parameters, such as air requirements and solids production, can be estimated. However, when considering the design of inlet works, screens, pumps and conduits throughout a plant, septage is distinctly dissimilar to sewage. The waste is anaerobic and odoriferous. It contains hair, plastic material and grit that clog and wear pumps and conduits. Unclogging pumps, air draft tubes and screens produces operational problems and is time-consuming. Personal contact with septage, for maintenance purposes, is highly objectionable--a fact the design engineer must be aware of.

SECTION 2

CONCLUSIONS

SEPTAGE TREATABILITY

Treatment with Sewage at Municipal Plants

Septage is readily treated biologically when combined with domestic sewage. Microbial cultures found in conventional activated sludge and extended aeration processes are well adapted for rapid assimilation of septage organics. Microbiological examination of mixed liquor, dissolved oxygen uptake measurements and effluent monitoring have shown conclusively that septage is effectively oxidized when processes are loaded within design capacities.

Septage is about 50 times as concentrated as domestic sewage. A constant 2% addition of septage approximately doubles the organic input to an aeration basin at an extended aeration facility or doubles the solids loading on a primary clarifier at a conventional activated sludge facility. Secondary aeration basins at conventional plants receive about one fifth of the influent septage organic loading since the major fraction of organics in septage is usually associated with suspended solids, which are effectively removed in primary clarification. Nutrient:carbon ratios are lower for septage than for sewage, but septage provides adequate nutrients for biological oxidation.

The obvious variability of domestic septage chemical characteristics is not overly critical at municipal treatment facilities where storage and dilution tend to attenuate the impact of a single concentrated truckload.

Without the addition of chemicals septage dewaters slowly and cannot be processed on a vacuum filter. This study has shown that a secondary sludge, derived from a combination of sewage and septage, vacuum-filtered well with the addition of polymer. A secondary sludge derived from sewage and septage combined with primary sludge containing septage also dewatered well on a vacuum filter with the addition of lime.

Recommended Septage Loading

The quantity of septage that a wastewater treatment facility can handle is normally limited only by available aeration and/or solids handling capacity. Aeration capacity is most critical at extended aeration plants where the entire quantity of septage undergoes oxidation. Solids dewatering and disposal facilities are often taxed at existing plants but where capacity exists it can be well utilized for septage disposal.

An existing extended aeration facility that is loaded with sewage to 25% of its design capacity can reasonably be expected to take a 3% (by volume) addition of septage; a plant loaded to 50% can handle about 2%. At 75% capacity the recommended septage loading is 1%. These estimates are for constant septage addition or frequent periodic additions, i.e., every hour or half hour. Loading up to and exceeding 5% of the sewage flow is possible if an extended aeration plant has adequate aeration capacity or is provided with excess capacity specifically for septage.

When septage is fed to aeration basins in slug loads as it is received, the loading limit should be about half of the values suggested for constant loading. Obviously, experience at existing facilities is the best measure of available capacity for septage loading.

While there are definite advantages to feeding septage to extended aeration plants at constant rates, this method of addition may not be necessary at conventional activated sludge plants because primary clarifiers function well with either constant or shock loading. The method of feeding septage to plants does not affect dewatering processes.

DESIGN PARAMETERS FOR NEW FACILITIES

Dissolved Oxygen

The design of aeration facilities for extended aeration and activated sludge plants can be based upon combined sewage and septage COD or BOD input to the secondary process. Average sewage and septage characteristics should be used for design. Oxygen transfer efficiency and oxygen utilization estimates should be selected from within the range of conventional values for the specific process used.

Oxygen utilization for septage fed at constant rates in this study averaged 0.7 kg O_2/kg BOD_5 and 0.3 kg O_2/kg COD. Oxygen transfer was about the same with or without septage addition--about 1.3 kg O_2/kw h (2.2 lb/hp-h). Generally, increasing organic loading by adding septage depresses dissolved oxygen levels in an aeration process, which in turn increases the efficiency of oxygen transfer.

Nitrogen

Nitrification and denitrification monitored during the course of this research were caused by both organic loading and mixed liquor dissolved oxygen concentration. Without the addition of septage the Medfield treatment plant normally converts ammonia to nitrate in the first aeration basin. Denitrification occurs in the remaining aeration basins which usually carry little dissolved oxygen. Increased organic loading derived from septage inhibited nitrification in the first basin. Absence of dissolved oxygen in the remaining basins resulted in high ammonia concentrations in secondary effluent. When dissolved oxygen levels were increased in the second basin nitrification was again complete and denitrification followed in the remaining two basins.

Sludge Production

Thickener and vacuum filter design for extended aeration and conventional activated sludge plants can be based upon total anticipated solids in the combined influent sewage and septage. A reasonable estimate is to assume the septage solids contribution at 50 times that of an equivalent volume of raw sewage.

In the course of this study, dewatering was monitored for secondary sludge derived from septage and sewage at Medfield, and a combination of primary sludge containing septage and secondary sludge derived from septage and sewage at Marlborough. In each case septage solids were equal to or exceeded the sewage contribution. Septage did not affect dewatering either by changing the cake or filtrate characteristics or by requiring process changes. Chemical conditioners were fed on the basis of dewatering process influent solids quantity, irrespective of whether the solids were derived from sewage or septage.

Handling and Receiving

Septage can contain hair, grit, and stringy and plastic materials. It is highly odoriferous and a health hazard. Odors permeate clothing and body tissue. This combination of physical characteristics make septage a particularly difficult material to feed at controlled rates, to screen or to pass through small size conduits and pumps.

Controlled septage feeding requires storage facilities and hydraulic transmission systems. While constant feeding or feeding at selected times has distinct advantages, particularly at extended aeration facilities, there are inherent practical problems. These can be eliminated only through careful design that considers the nature of septage.

There are practical advantages to having receiving stations at municipal plants designed specifically for septage addition. Holding-tanks permit flexibility in process feeding and processes selection. Septage odors can be controlled, grit can be removed and separate treatment provided when desired.

A possible receiving system would consist of an enclosed aerated grit chamber with sludge removal and odor control equipment. Provision should be made for bleeding sewage through the chamber for continuous septage displacement. Conduit size should be equal to or in excess of 15 cm (6 inches) for septage transfer.

COSTS

Cost of Septage Treatment

Septage treatment costs can be divided into three categories: capital equipment, operation and maintenance, and disposal site acquisition. Capital and operation costs are minimized by expeditiously moving septage to dewatering processes. Capital costs are site specific but generally involve the cost of solids handling equipment, designed on a solids basis, and aeration facilities, based upon organic loading. Receiving station costs would be comparable with conventional aerated grit chamber costs plus the cost of an enclosed receiving area and pumps if needed.

Operation and maintenance costs for septage addition are largely dependent upon whether or not a plant has primary clarification and the economics of scale. For example, the operation and maintenance cost of treating septage at Medfield was between $2 and $3/cu m ($8 and $12/1000 gal). This 5,700 cu m/day (1.5 mgd) plant had a sewage input averaging 1,040 cu m/day (0.28 mgd) and was operated as an extended aeration facility.

Processes in use at Marlborough were loaded to full capacity at 12,100 cu m/day (3.3 mgd) and septage cost about $0.54/ cu m ($2/1000 gal). Septage loading was 2% in both cases. The cost difference was due to the high power cost of oxidizing septage organics at Medfield and the economic advantages inherent at the larger plant.

SECTION 3

EXPERIMENTAL FACILITIES

MEDFIELD WASTEWATER TREATMENT PLANT

Septage addition was monitored at three wastewater treatment plants: Medfield, Marlborough, and a University-operated pilot plant. The Medfield treatment plant is a new conventional activated sludge facility incorporating primary and secondary treatment, tertiary sand filtration, solids thickening, and vacuum filtration. Medfield is characteristic of new treatment plants that receive only a fraction of their design sewage flow, and accept septage. As a result of low sewage flow, this plant is operated in an extended aeration mode. As sewers replace septic tanks in the community, sewage flow will increase and septage input will decline, unless septage is accepted from adjacent communities. During the sewer construction period, the plant is accepting the contents of abandoned systems in addition to routine pumpage. The Medfield plant does not, at present, accept septage from adjacent communities, although there is expressed interest in doing so. Establishing an equitable price for deliveries has been a deterrent.

Figure 1 is a schematic diagram of the Medfield facility. Process units in use during this monitoring study are indicated with bold lines. In-coming sewage was screened in the intake structure and pumped to one compartment of the dual-compartmented aerated grit chamber. The other compartment was used during this study to store and feed septage. Sewage and septage combined in a channel that separates the two chambers, and the mixture flowed through conduits to aeration basin 1. The primary settling tanks are bypassed in the extended aeration mode of operation. One of the primary tanks was used for septage storage.

Four of the six aeration tank sections were in use during monitoring. Basin 1 received sewage and septage from the grit chambers and sludge returned from the secondary clarifier. Wastewater flowed from basin 1 to basin 2, and sequentially through 3 and 4 to a single secondary clarifier.

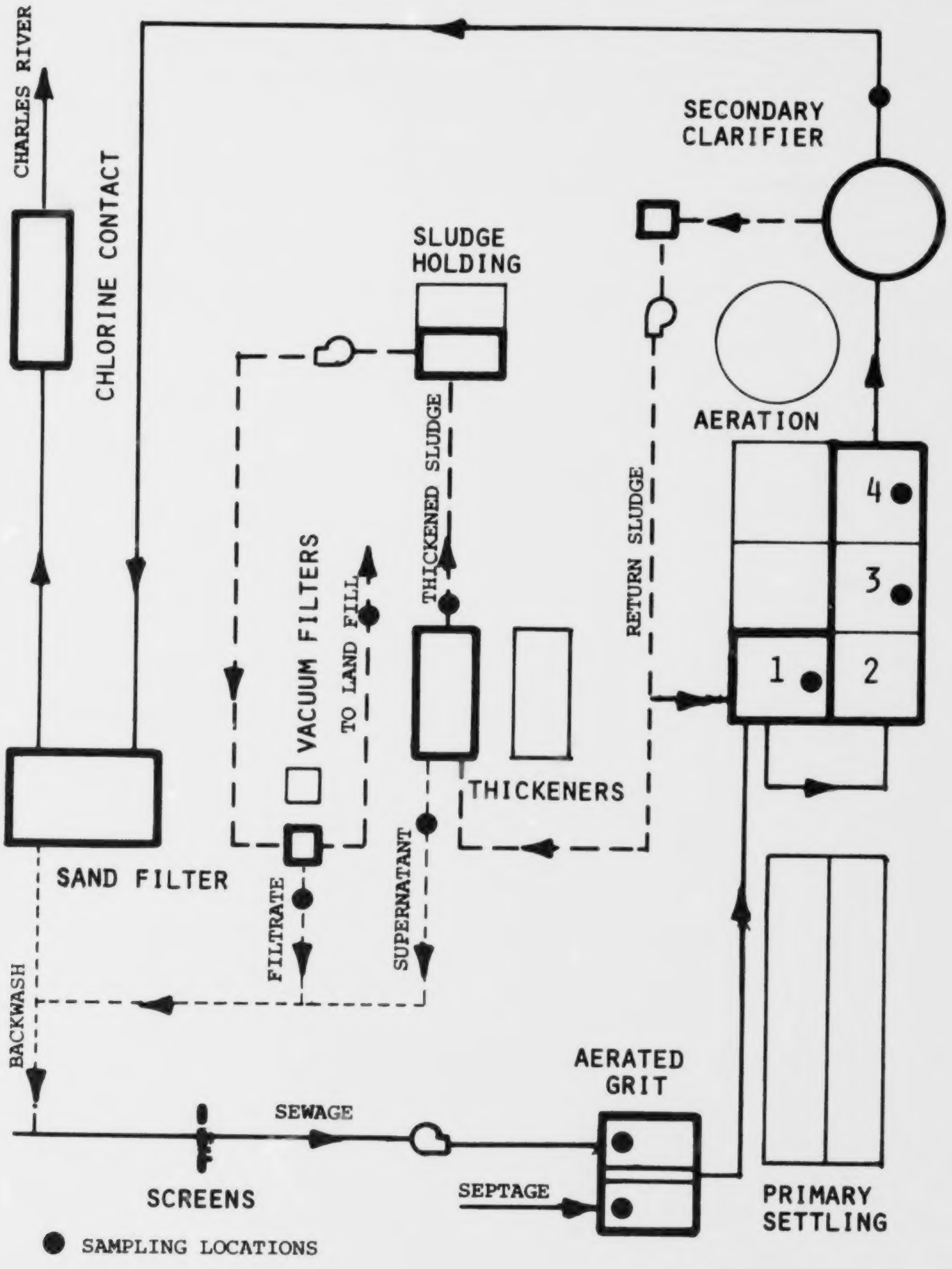
CHARLES RIVER
CHLORINE CONTACT
SECONDARY CLARIFIER
SLUDGE HOLDING
AERATION
THICKENED SLUDGE
RETURN SLUDGE
VACUUM FILTERS
TO LAND FILL
4
3
1
2
THICKENERS
SAND FILTER
FILTRATE
SUPERNATANT
BACKWASH
AERATED GRIT
SEWAGE
SEPTAGE
SCREENS
PRIMARY SETTLING
● SAMPLING LOCATIONS

Figure 1. Process schematic for the Medfield plant.

Sludge collected at the bottom of the secondary clarifier was lifted through four draft tubes and held in the equalizing chamber located adjacent to the return sludge pumping station. The sludge was either returned to aeration basin 1 or pumped to one of two flotation thickeners. Thickened sludge was vacuum filtered and land-filled on property adjacent to the plant. Process dimensions are summarized in Table 3, and listed in detail in Appendix A-1.

TABLE 3. MEDFIELD TREATMENT PLANT PROCESS DIMENSIONS

Design flow rate: 0.066 cu m/sec (1.5 mgd)
Average flow during test period: 0.012 cu m/sec (0.28 mgd)

Aerated Grit Chamber

Volume: 56.8 cu m (2,005 cu ft) (15,000 gals)
Detention time during test period: 1.29 hrs
Detention time at design flow: 0.48 hrs

Aeration Tanks

Number of compartments in use: 4
Compartment volume: 302 cu m (10,800 cu ft) (80,800 gals)
Detention time during test period: 7.08 hrs/compartment
Detention time at design flow: 1.29 hrs/compartment

Final Clarifier

Surface area: 117 sq m(1,257 sq ft)
Volume: 316 cu m (11,310 cu ft) (84,600 gals)
Detention time during test period: 7.25 hrs
Detention time at design flow: 2.71 hrs
Overflow rate during test period: 8.87 cu m/sq m-day (219 gpd/sq ft)
Overflow rate at design flow: 24.4 cu m/sq m-day (602 gpd/sq ft)

MARLBOROUGH EASTERLY WASTEWATER TREATMENT PLANT

The Marlborough Easterly plant is a 20,800 cu m/day (5.5 mgd), two-stage activated sludge process, incorporating nitrification and phosphorous removal. Figure 2 is a schematic diagram of the treatment plant, with the processes in operation during monitoring indicated with bold lines.

Raw sewage passes through one compartment of a dual-compartmented aerated grit chamber and flows to a distribution box, where it combines with waste-activated sludge and septage. The combined flow is discharged to a single primary clarifier.

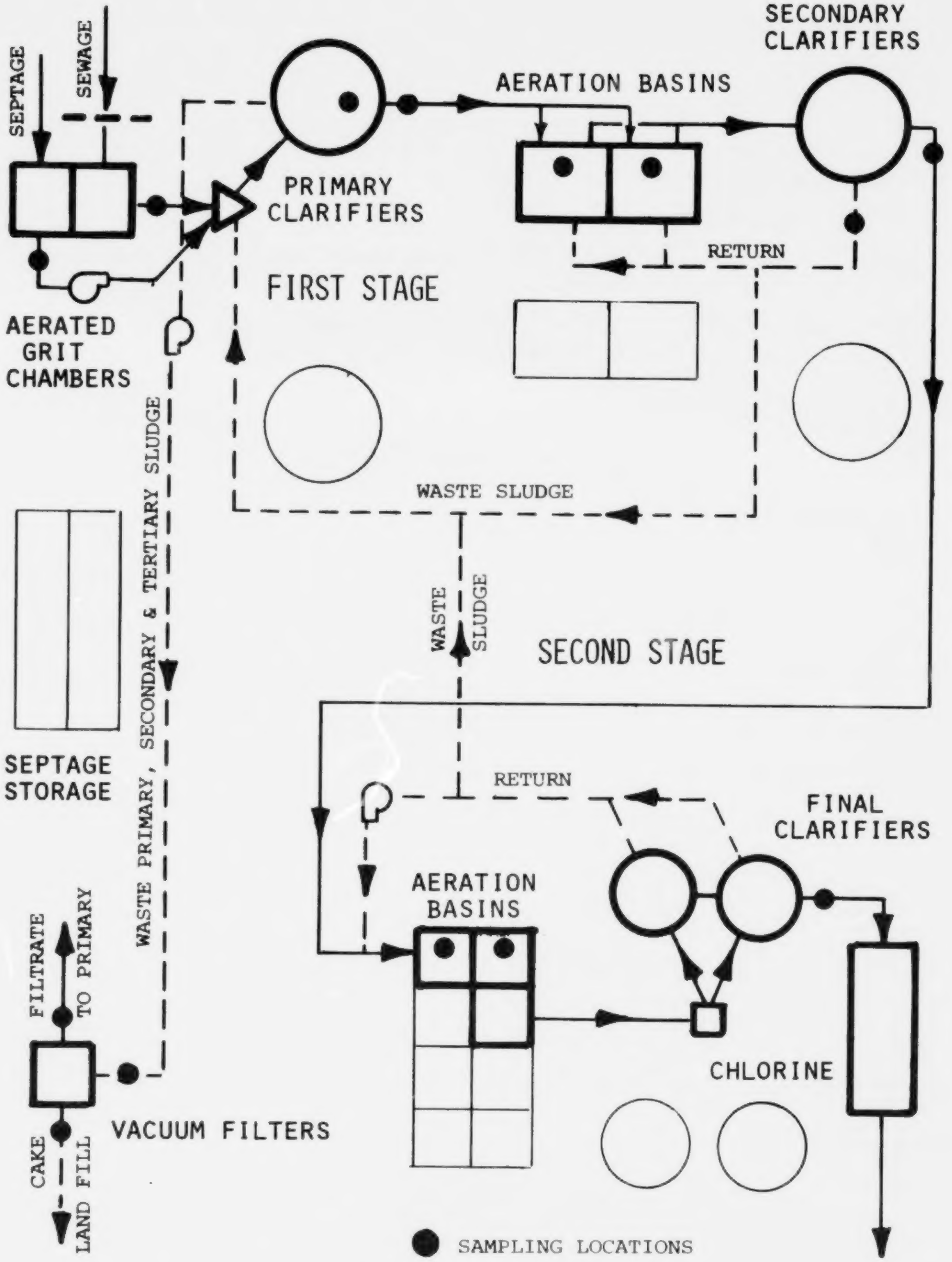
SEPTAGE
SEWAGE
PRIMARY CLARIFIERS
AERATION BASINS
SECONDARY CLARIFIERS
AERATED GRIT CHAMBERS
FIRST STAGE
RETURN
WASTE SLUDGE
WASTE PRIMARY, SECONDARY & TERTIARY SLUDGE
SEPTAGE STORAGE
WASTE SLUDGE
SECOND STAGE
RETURN
FINAL CLARIFIERS
AERATION BASINS
FILTRATE TO PRIMARY
CHLORINE
VACUUM FILTERS
CAKE LAND FILL
● SAMPLING LOCATIONS

Figure 2. Process schematic for the Marlborough Easterly treatment plant.

The plant consists of two parallel process trains with facility for crossover at every process. During monitoring, half of the available treatment units were in use for a flow slightly greater than one-half of the plant design capacity. This enabled process loading essentially at design capacities. Process loading characteristics and capacities are shown in Table 4. Dimensions are shown in detail in Appendix A-2.

TABLE 4. MARLBOROUGH TREATMENT PLANT PROCESS DIMENSIONS

Design flow rate: 0.24 cu m/sec (5.5 mgd)
Average flow during test period: 0.14 cu m/sec (3.3 mgd)

Aerated Grit Chamber

Volume: 62.1 cu m(2,194 cu ft) (16,400 gals)
Detention time during test period: 0.12 hrs
Detention time at design flow: 0.14 hrs

Storage Tanks

Volume: 254 cu m (8,957 cu ft) (67,000 gals)

Primary Settling Tanks

Surface area: 356 sq m (3,848 sq ft)
Volume: 1,318 cu m (46,180 cu ft) (345,440 gals)
Detention time during test period: 2.51 hrs
Detention time at design flow: 3.01 hrs
Overflow rate during test period: 35.1 cu m/sq m-day
(857 gpd/sq ft)
Overflow rate at design flow: 29.1 cu m/sq m-day
(715 gpd/sq ft)

Aeration Tanks - First Stage

Number of compartments in use: 2
Compartment volume: 1,089 cu m (38,400 cu ft) (287,200 gals)
Detention time during test period: 4.18 hrs
Detention time at design flow: 5.01 hrs

Secondary Clarifiers

Surface area: 590 sq m (6,362 sq ft)
Volume: 2,157 cu m (76,200 cu ft) (570,000 gals)
Detention time during test period: 4.15 hrs
Detention time at design flow: 4.98 hrs
Overflow rate during test period: 21.1 cu m/sq m-day
(519 gpd/sq ft)
Overflow rate at design flow: 17.7 cu m/sq m-day (432 gpd/sq ft)

(continued)

TABLE 4. (continued)

Aeration Tanks - Second Stage

Number of units in use: 1
Unit volume: 2,178 cu m (76,800 cu ft) (574,465 gals)
Detention time during test period: 4.20 hrs
Detention time at design flow: 5.00 hrs

Nitrification Settling Tanks

Surface area: 468 sq m (5,027 sq ft)
Volume: 2,157 cu m (76,200 cu ft) (570,000 gals)
Detention time during test period: 4.15 hrs
Detention time at design flow: 5.04 hrs
Overflow rate during test period: 13.4 cu m/sq m-day (328 gpd/sq ft)
Overflow rate at design flow: 11.1 cu m/sq m-day (247 gpd/sq ft)

Plant laboratory data showed that the first stage at Marlborough normally reduces carbonaceous biochemical oxygen demand, BOD_5, from an average of 100 mg/l to about 11 mg/l. The second stage further reduces BOD_5 to 2.6 mg/l and converts about 15 mg/l of ammonia nitrogen to nitrate nitrogen.

Primary and secondary sludges were wasted daily during the course of the study. Sludge from the nitrification stage was not wasted during the monitoring period. When secondary and nitrification stage sludges are wasted they are returned to a primary clarifier, combined with primary sludge and sent to a vacuum filter. Ferric chloride and lime are used as sludge conditioners.

UNIVERSITY OF LOWELL PILOT PLANT

The Department of Civil Engineering at the University of Lowell operates a 30.3 cu m/day (8,000 gal/day) Davco extended aeration package plant for research and instruction. The plant is located on the University campus on the banks of the Merrimack River, near a 30 inch diameter brick combined sewer outfall. The sewer serves several University dormitories, the student union, a cafeteria, and a number of homes in Lowell. The process is shown schematically in Figure 3, and operating parameters are shown in Table 5. Sewage was pumped continuously from the outfall sewer to a weir box that provides the plant with a constant inflow and returns excess flow back to the sewer, upstream of the pump intake. Septage was continuously mixed in a tank and fed by an airlift pump that was on a timed intermittent schedule. The plant air system consists of a single air compressor which feeds four coarse bubble-diffusers in the aeration basin, and provides air for sludge return, clarifier scum removal and septage feeding. Sludge wasting was monitored by pumping mixed liquor from the aeration basin to a graduated waste-measurement box.

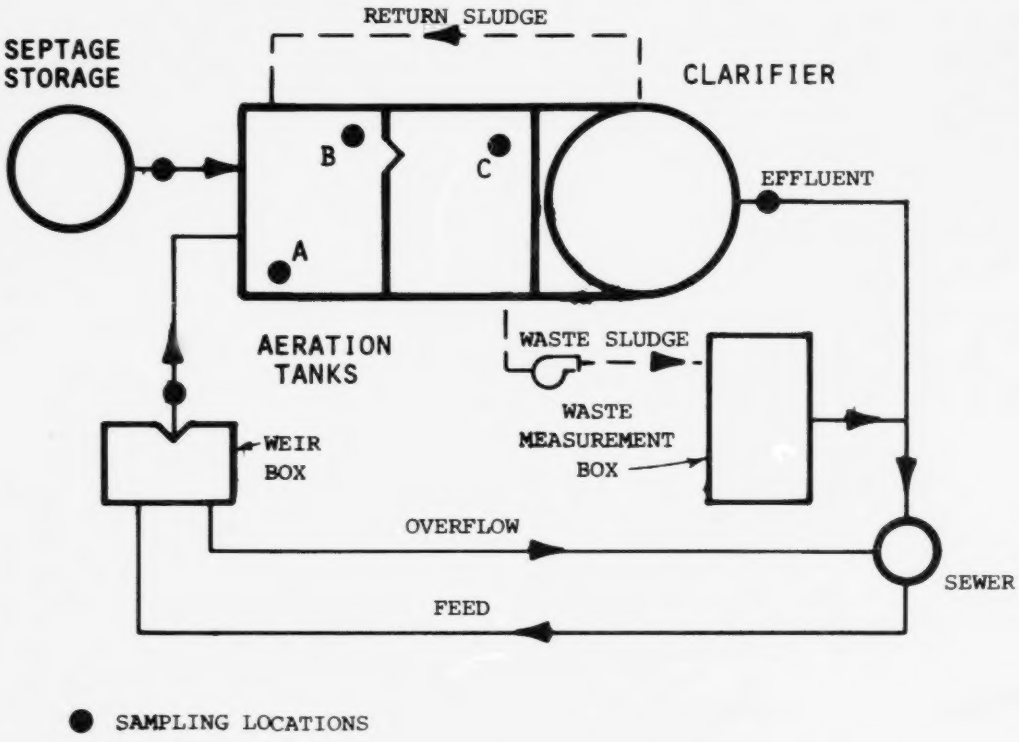
RETURN SLUDGE
SEPTAGE STORAGE
CLARIFIER
B
C
A
EFFLUENT
AERATION TANKS
WASTE SLUDGE
WASTE MEASUREMENT BOX
WEIR BOX
OVERFLOW
SEWER
FEED
● SAMPLING LOCATIONS

Figure 3. Process schematic for the University of Lowell plant.

TABLE 5. UNIVERSITY OF LOWELL PILOT PLANT PROCESS DIMENSIONS

Flow rate for extended aeration: 30.3 cu m/day (1,070 cu ft/day) (8,000 gals/day)
Flow rate for conventional process: 109.0 cu m/day (3,850 cu ft/day) (28,800 gals/day)

Aeration Tank

Volume: 30.2 cu m (1,070 cu ft) (8,000 gals)
Detention time extended aeration: 24 hrs
Detention time conventional process: 6.7 hrs

Settling Tank

Surface area: 5.9 sq m (63 sq ft)
Volume: 15.5 cu m (547 cu ft) (4,090 gals)
Detention time extended aeration: 12.3 hrs
Detention time conventional process: 3.4 hrs
Overflow rate extended aeration: 5.17 cu m/sq m-day (127 gpd/sq ft)
Overflow rate conventional process: 18.6 cu m/sq m-day (457 gpd/sq ft)

SECTION 4

MONITORING PROGRAM

SUMMARY OF PROCEDURES

A three phase experimental program was conducted at each of the three plants. Initially, plants were monitored seven days per week for periods of two to three weeks without septage addition. During this first phase of the study, samples were collected and laboratory tests performed, while incoming septage was stored for later use. Phase 1 was designed to acquire a data base prior to septage addition.

During the second stage of testing, septage was added at constant rates for periods of several days to three weeks. The objectives were to monitor process performance and effluent quality under various loading levels, and, if possible, to stress the plants with large quantities of septage. The two municipal plants were fed as much septage as could be obtained and stored. The University plant was stressed to failure, both in the continuous loading Phase 2 and in the slug loading experiments conducted under Phase 3. During Phase 3, Medfield and Marlborough were slug-loaded daily for a series of two to four day periods.

Composite and grab samples were collected at locations in the plants on daily, biweekly, and weekly schedules. Sampling locations were set and analysis schedules were designed to follow solids, organics, nitrogen, phosphorus and other constituents through the plants.

Table 6 summarizes chemical analyses performed at the University of Lowell laboratory, and, when appropriate, at sampling locations at the three wastewater treatment plants. The table is a general overview of the analytical work; individual analytical results are given in the appendices. Sampling points at each plant are shown in Figures 1, 2, and 3. The analytical methods used are summarized in Table 7.

MONITORING PROGRAM AT MEDFIELD

Table 8 is a summary of tests conducted at Medfield during the fall of 1977. The daily routine at Medfield during Phase 1 consisted of obtaining plant operating data for the preceding

TABLE 6. SCHEDULE OF SAMPLES AND ANALYSES

Plant	Influent	Septage	Primary Effluent	Secondary Effluent	Tertiary Effluent	Mixed Liquor	Return Sludge	Thickener Supernatant	Thickened Sludge	Vacuum Filter Filtrate	Cake
Medfield	X	X		X		X	X	X	X	X	X
Marlborough	X	X	X	X	X	X	X			X	X
U. of Lowell	X	X		X		X					
Sample Frequency											
Daily (D)	D	D	D	D	D	D	D			D	D
Semi-weekly (SW)								SW	SW		
Weekly (W)								W	W	W	W
Type of Sample											
Composite (C)	C		C	C	C						
Grab (G)		G				G	G	G	G	G	G
Analyses											
COD-Total	X	X	X	X	X			X		X	
COD-Soluble	X		X	X	X					X	
BOD-Total	X	X	X	X	X			X		X	
BOD-N Suppressed	X	X	X	X	X			X		X	
Total Solids	X	X	X	X	X	X	X	X	X	X	X
Total Volatile Solids	X	X	X	X	X	X	X	X	X	X	X
Suspended Solids	X	X	X	X	X	X	X	X		X	
Volatile Susp. Solids	X	X	X	X	X	X	X	X		X	

(continued)

TABLE 6. (continued)

	Influent	Septage	Primary Effluent	Secondary Effluent	Tertiary Effluent	Mixed Liquor	Return Sludge	Thickener Supernatant	Thickened Sludge	Vacuum Filter Filtrate	Cake
Ammonia-N	X	X	X	X	X	X	X			X	
Nitrate-N	X		X	X	X	X	X			X	
Total Kjeldahl N	X	X	X	X	X	X	X			X	X
Total Phosphorus	X	X	X	X	X					X	
Grease	X	X	X	X	X						
pH	X	X	X	X	X	X	X			X	
Temperature	X	X	X	X	X	X	X				
Alkalinity	X	X	X	X	X	X	X				
Dissolved Oxygen	X		X	X	X	X					
D.O. Uptake						X					
Settlometer						X	X				
Capillary Suction Time							X		X		
Turbidity				X	X						
Metals	X	X	X	X	X			X		X	X
Oxidation Reduction Potential		X									

day, collecting samples, and conducting analyses. Influent and effluent samplers (Isco Model 1680) composited four samples each hour into a container. Quantities from each of the twenty-four containers were composited in a large container proportioned in accordance with the recorded plant flow record. Grab samples of mixed liquor and returned sludge were also taken daily. Cake, thickened sludge, thickener and vacuum filter supernatant were taken whenever the plant wasted solids, about once each week. Samples were returned to the University laboratory within two hours of collection.

TABLE 7. ANALYTICAL PROCEDURES

Analyses	Std. Methods Sect.*	EPA Tech. Transfer Sect.**	Comments
COD-Total	508	00340	
COD-Soluble	508	00340	sample filtered (0.45 μm)
BOD-Total	507	00310	
BOD-N Suppressed	507	00310	added 10 ml of 3.0M NH_4Cl to 300 ml BOD bottle
Total Solids	208A	00500	
Total Volatile Solids	208E	00505	
Suspended Solids	208C	00530	
Volatile Susp. Solids	208E	00535	
Ammonia-N		00610	Orion Model 95-10
Nitrate-N	419B		Orion Model 92-07
Total Kjeldahl-N	421	00625	
Total Phosphorus	425E		Persulfate Digestion
Grease		00556	Separatory Funnel
pH	424	00400	Corning
Temperature	212	00010	
Alkalinity	403	00410	
Dissolved Oxygen	422F	00299	YSI Model 54
D.O. Uptake	213B		
Settlometer	213C		
Capillary Suction Time			Triton
Turbidity	214A		Hach
ORP			Corning
Chromium	301A	01034	
Cadmium	301A	01027	
Copper	301A	01042	
Nitrate	301A	01067	
Lead	301A	01051	
Zinc	301A	01092	

*American Public Health Association, Standard Methods for the Examination of Water and Wastewater (Washington, D.C., 1976.)

**Environmental Protection Agency, Technology Transfer, Manual of Methods for Chemical Analysis of Water and Waste, (1974).

TABLE 8. TEST PERIODS AND SEPTAGE LOADING AT MEDFIELD

Phase	Type of Loading	Consecutive Loading Days*	Starting Date	Completion Date	Average Septage Loading - % of Daily Flow
1	No Loading	22	8/22	9/12	0
2A	Continuous	21	9/13	10/3	2.0
3A	Shock	3 + 2	10/14	10/18	1.8**
2B	Continuous	7 + 1	11/1	11/8	3.8
3B	Shock	4 + 1	11/14	11/18	2.6**

* Indicates number of days septage fed plus the monitored recovery period.

** Percent of average daily flow is shown. Shock loading duration and application rates are detailed in the text.

Temperature, pH, and dissolved oxygen were measured at sampling locations. Settlometer and dissolved oxygen uptake tests were conducted in the plant laboratory.

The routine was continued during the continuous septage feed study, Phase 2, with the addition of daily septage sampling from the aerated grit chamber. Septage was also sampled as it was discharged from hauling trucks in an effort to exert some control of septage solids and organic concentration.

A schematic of the septage feed system used at Medfield is shown in Figure 4. Septage was discharged from haulers' trucks to a screening box used to remove hair and plastic materials. Screen wire was 2 inches on-center; anything less clogged with hair from a single load. Vibrating screens were not available. In Phase 2A screened septage was pumped from the aerated grit chamber to a weir box on a 15 minute cycle. The pumping period was about seven minutes. In Phase 2B the weir box was eliminated and the cycle increased to 30 minutes. The quantity pumped from the aerated grit chamber each day was determined by measuring changes in liquid level.

During the first shock load test, Phase 3A, the drain plug was pulled in the aerated grit chamber, sending 18.9 cu m (5,000 gals) of septage to the raw sewage lift station. This was repeated on the second day, followed by 25.4 cu m (6,700

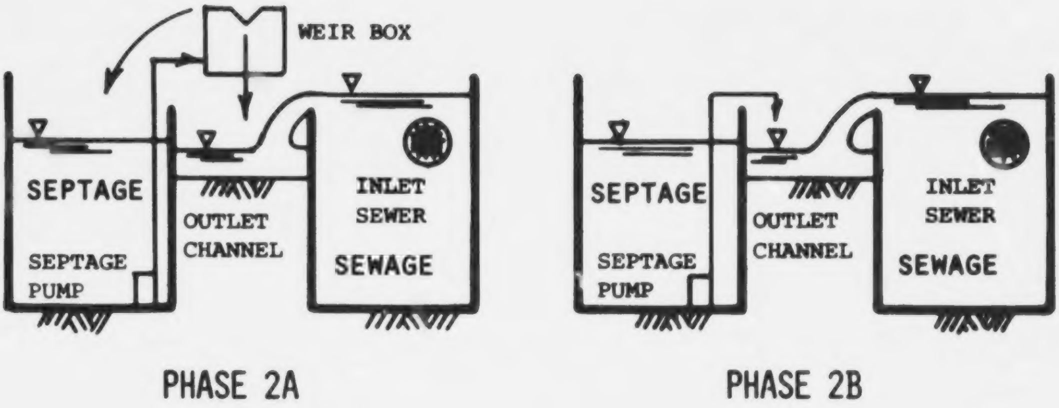
WEIR BOX
SEPTAGE
SEPTAGE PUMP
OUTLET CHANNEL
INLET SEWER
SEWAGE
PHASE 2A
SEPTAGE
SEPTAGE PUMP
OUTLET CHANNEL
INLET SEWER
SEWAGE
PHASE 2B

Figure 4. Septage feed systems - Medfield.

gals) on the third day. The pumps returned the slugs of septage to the 56.8 cu m (15,000 gals) aerated grit chamber compartment containing sewage. The mixture was then displaced from the grit chamber by incoming sewage over a period of about four hours. The rate of septage input to aeration tank 1 based upon total solids analyses during Phase 3A is shown in Figure 5. The total solids curve is representative of septage displacement from the aerated grit chamber to the aeration basins.

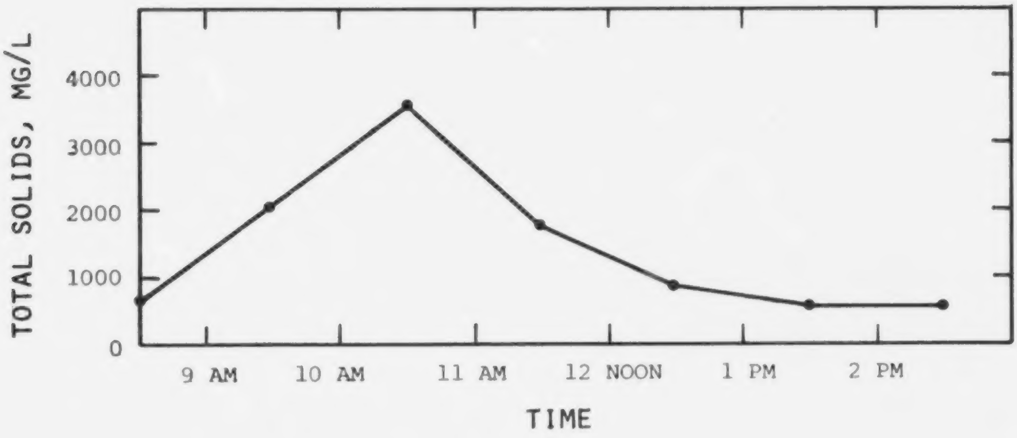

Figure 5. Influent total solids - Medfield - Phase 3.

During the second shock load test, Phase 3B, portable pumps and a septage hauling truck were used to pump septage directly from the septage compartment of the aerated grit chamber and from the primary tank to the aeration tank inlet. The plant was loaded on each of four successive days; 29.5 cu m (7,780 gals) on each of the first three days and 37.9 cu m (10,000 gals) on the fourth day.

MONITORING PROGRAM AT MARLBOROUGH

A three phase monitoring program was initiated at the Marlborough Easterly wastewater treatment plant during the spring of 1978. The testing schedule is shown on Table 9. Monitoring began after winter snow-melt when infiltration had subsided, plant flows were down and septage deliveries on the upswing. During Phase 1 the plant was monitored for 17 days without septage addition beginning on April 17. Composite samples of plant influent, primary effluent, secondary effluent and final effluent were collected for analyses every day during the period. Grab samples of mixed liquor and returned sludge were also taken daily from both the secondary treatment process (first stage) and the nitrification process (second stage). Combined primary and secondary sludge, and cake and vacuum filtrate were sampled whenever the plant wasted solids.

TABLE 9. TEST PERIODS AND SEPTAGE LOADING AT MARLBOROUGH

Phase	Type of Loading	Consecutive Loading Days*	Starting Date	Completion Date	Average Septage Loading % of Flow
1	No Loading	22	4/17	5/7	0
2A	Continuous	3	5/8	5/10	1.25
2B	Continuous	1.75	5/16	5/18	2.14
3A	Shock	3 + 2	5/30	6/2	0.83
3B	Shock	2 + 1	6/7	6/9	2.05

* Indicates number of days septage fed plus the monitored recovery period.

During Phase 2 septage was fed continuously. Septage samples were collected daily, as were the composite and grab samples taken during Phase 1. An effort was made to obtain septage samples that were representative of the entire mass of material fed during a particular test, either by mixing holding tanks or by sampling various locations in a tank.

The septage storage and feed system used for continuous and shock loading is shown on Figure 6. The system consisted of a 227 cu m (60,000 gal) storage basin that had been used as an aeration basin for an old plant that previously existed on the site. The aeration system was used to mix the septage. A gasoline-motor-driven sludge pump was used to transfer septage from storage to one 53 cu m (14,000 gal) aerated grit chamber compartment. The plant grit chamber is a dual-compartmented unit; one side is normally used as a septage receiving tank.

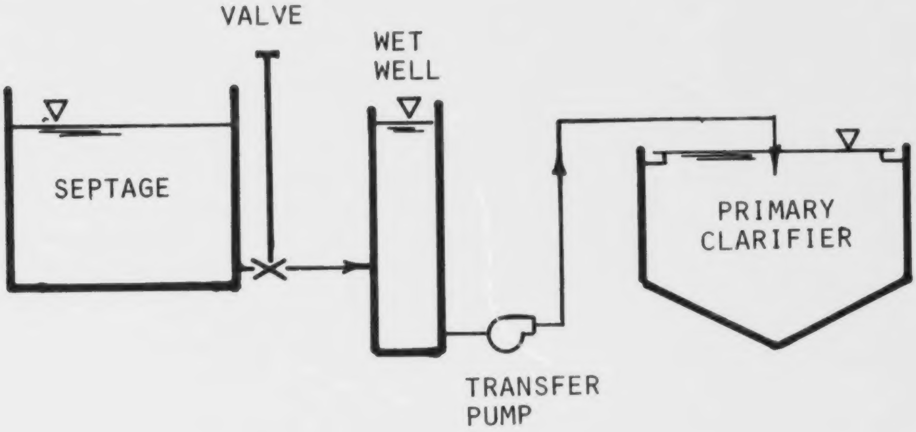

Figure 6. Septage feed system - Marlborough.

Septage was discharged from the grit chamber to a manhole, and from there to a 22.7 cu m (6,000 gal) wetwell adjacent to the secondary clarifiers. The 15.2 cm (6 inch) wetwell centrifugal pump was cycled on a time clock enabling controlled input to the primary clarifier during Phase 2.

During the first continuous loading test, 110 cu m (29,000 gal) of septage were fed over a period of 24 hours. The wetwell pump discharged 2.27 cu m (600 gal) in each cycle. It cycled on for one minute every 30 minutes. Septage held in storage and that provided by incoming trucks during this test period enabled three days of continuous feeding. During the second Phase 2 test, a high input by haulers plus accumulated storage enabled feeding a total of 375 cu m (99,000 gal) over a period of 42 hours. This was equivalent to feeding the plant a truckload of septage every half hour, twenty-four hours per day for close to a two day period.

The first shock loading test began on May 30 and was repeated on the following three days. The entire contents of the aerated grit chamber compartment, the transmission piping and the wetwell, 79.5 cu m (21,000 gal) were discharged to the primary clarifier in a period of 30 minutes. During the second test this was repeated on each of two days, but, in addition to the 30 minute discharge of 79.5 cu m (21,000 gal), an added 68.1 cu m (18,000 gal) of septage was pumped at the same time from storage. The pumped discharge took two hours. On the second day of this test, an additional 45.4 cu m (12,000 gal) was also fed during the afternoon. The last continuous and shock loadings were the maximum loadings possible at the plant with available storage and pumping facilities. These loadings far exceeded normal or potential input to the plant.

A principal objective at Marlborough was to determine the effects of high level septage addition on primary clarification and septage solids reduction in primary clarification. To accomplish this goal, primary clarifier samples were taken at a mid-location near the surface, at mid-depth, near the bottom, and at the effluent weir. Samples were initially collected at one-half hour intervals, followed by longer intervals as the effects of a shock load passed through the basin.

RESEARCH AT THE UNIVERSITY PILOT PLANT

Septage research at Lowell began during 1976 under a grant from the Commonwealth of Massachusetts, Department of Environmental Quality Engineering. The work was conducted at the University pilot plant which, at that time, was operated as an extended aeration process. Continuous loading tests were conducted with long aeration basin retention and high mixed liquor solids concentration. This initial study has been combined with this research, and the results of loading the extended aeration process are given in subsequent sections of this report. The test schedule is shown on Table 10. The sewage and septage feed systems are shown on Figure 7.

During 1977 and 1978 the University plant was slug loaded in the extended aeration mode of operation and was also operated as a conventional facility, i.e., with an aeration basin retention period and mixed liquor solids concentration, akin to conventional processes, but without primary clarification.

Extended Aeration Mode of Operation

Plant operation in the extended mode began by seeding with 22.7 cu m (6,000 gals) of mixed liquor obtained from the Billerica, Massachusetts extended aeration plant. The initial influent flow was 30.3 cu m (8,000 gals) per day.

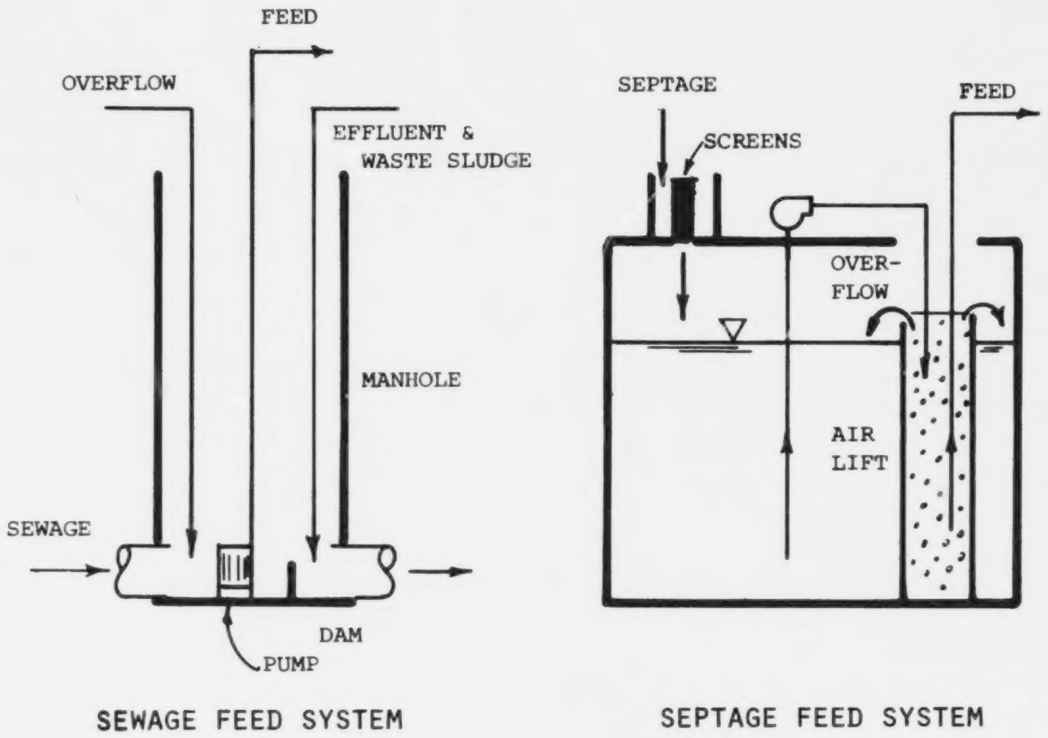
FEED
OVERFLOW
EFFLUENT &
WASTE SLUDGE
MANHOLE
SEWAGE
DAM
PUMP
SEWAGE FEED SYSTEM
SEPTAGE
SCREENS
FEED
OVER-
FLOW
AIR
LIFT
SEPTAGE FEED SYSTEM

Figure 7. University of Lowell pilot plant feed systems.

After seven weeks of operation in this baseline mode, Phase 2 was begun and 75.7 liters/day (20 gals/day) of septage was introduced to the plant. While feeding septage, mixed liquor suspended solids, mixed liquor settleability, aeration basin dissolved oxygen, and effluent COD values were determined. BOD tests were run on influent, effluent, and septage samples. Microscopic inspections were frequently performed on the mixed liquor to determine sludge condition and to aid in operation. Influent sewage samples were composited over 24 hour periods; all other samples were grab.

The septage feed rate was increased by steps and the process allowed to stabilize at each selected feed rate. Process stability was determined by effluent COD and turbidity and sludge settleability. Increases were made over a five month period in accordance with the schedule shown on Table 10.

Sludge was returned to the aeration tank at four times the influent flow rate to minimize excessive retention in the

TABLE 10. TEST PERIODS AND SEPTAGE LOADINGS AT UNIVERSITY OF LOWELL PILOT PLANT

Phase	Mode	Type of Loading	Consecutive Loading Days*	Starting Date	Septage Loading % of Flow
3A	Extended Aeration	Shock	3 + 2	7/25	1.33
3B	Extended Aeration	Shock	3 + 2	8/ 1	2.63
1	Conventional	No Loading	17	3/12	0
2A	Conventional	Continuous	12	3/29	0.42
2B	Conventional	Continuous	6	4/10	0.82
3A	Conventional	Shock	3 + 2	5/ 3	1.04
3B	Conventional	Shock	2 + 2	5/18	1.82

*Indicates number of days septage fed plus the monitored recovery period.

clarifier. Sludge wasting was controlled by settleability. Settling requirements limited mixed liquor suspended solids concentration. As a result, F/M ratios rose with increasing septage loading.

Two series of shock loadings were investigated in Phase 3: 1.3% and 2.6% of the total daily sewage flow rate. Each series consisted of imposing the shock once a day for three consecutive days and monitoring the recovery period for either one or two days.

Conventional Mode of Operation

An approximation of conventional activated sludge operation was studied by increasing the influent flow rate. The average aeration basin detention time was just over six hours. At the increased flow rate the final clarifier detention time, about three hours, exceeded conventional operation.

Two periods of continuous loading were performed, followed by two shock loading periods. Loadings are shown on Table 10.

Sewage pump failures occurred frequently prior to Phase 3, causing problems in the aeration tanks, which, in turn, resulted in loss of the clarifier blanket during shock loading.

SECTION 5

RESULTS AT MEDFIELD

PHASE 1 - BASELINE FOR COMPARISON

The first phase of research at Medfield provided a baseline of information which was used to evaluate the effects of septage addition. During this three week period, septage was withheld from the plant. Sewage flow was only 14% of the design flow rate; aeration basin and final clarifier detention times were long, and loading parameters were low. Low sewage loading enabled large inputs of septage during subsequent phases of the research in contrast with the experiments at Marlborough, where the plant was fully loaded prior to septage addition.

Process Characteristics

Solids concentration in the aeration tanks at Medfield are normally maintained at comparatively high levels. As a result, the mean cell residence time, SRT (total microbial mass/rate of withdrawal) is considerably longer than the 20 to 30 day periods generally used for extended aeration plant design. Mean cell residence time and various other process parameters which characterize the operation at Medfield during Phase 1 are shown on Table 11. For comparison, design parameters commonly used for extended aeration process design are also included on this table.[5]

The combined effects of high mixed liquor solids concentration and low organic input are expressed in the food-to-microorganism ratio, F/M, which at 0.018 kg BOD_5/kg MLVSS-day is considerably below the range normally experienced at extended aeration plants. High oxygen utilization, 4.5 kg O_2/kg BOD_5 (lb O_2/lb BOD_5) is also a result of low organic loading and the basal metabolism requirements of the large mass of organisms maintained under aeration.

During Phase 1 the plant operated well along the endogenous respiration phase of the growth curve. Rotifers and ciliates were in abundance.

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[5] Metcalf and Eddy, Inc. Wastewater Engineering, McGraw Hill, New York, 1972, pg. 498.

TABLE 11. PROCESS CHARACTERISTICS - MEDFIELD PHASE 1

Characteristic	Phase 1 Average Values	Design Parameters Used for Extended Aeration Process*
Flow Rate, Q, cu m/sec (mgd)	0.009 (.206)	
Sludge Return Rate, Qr, cu m/sec (mgd)	0.018 (.420)	
Qr/Q	2.0	0.75-1.5
Aeration Basin Retention, hrs	37.6	18-36
Mixed Liquor Volatile Susp. Solids, mg/l	7580	
Mixed Liquor Volatile Susp. Solids, mg/l	4570	
F/M, kg BOD_5/kg MLVSS-day	0.018	0.05-0.15
Loading, gm BOD_5/cu m-day (lb BOD/1000 cu ft-day)	83.3(5.2)	160-400(10-25)
Mean Cell Residence, SRT, days	88	20-30
Oxygen Utilization, kg O_2/kg BOD	4.5	
Oxygen Utilization, kg O_2/kg COD	2.2	

*Metcalf and Eddy, Inc., Wastewater Engineering (New York: McGraw-Hill, 1972):498.

Influent Wastewater Characteristics

Characteristics of raw sewage sampled and analyzed during Phase 1 are shown on Table 12. The analytical results depict a typical residential community discharge, devoid of industrial wastes, but with some ground and surface water infiltration. The organic, solids, nitrogen and phosphorus concentrations shown in Table 12 characterize the plant influent as weak domestic sewage.[6] Standard deviations shown in Table 12 indicate variability in composite samples. The total average daily input to the plant during Phase 1 was 110 kg (242 lb) of organic material expressed as BOD_5 or 215 kg (474 lb) expressed as total COD. Daily total solids and total volatile solids input were 348 kg (766 lb) and 144 kg (318 lb), respectively.

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[6] Metcalf and Eddy, Inc. Wastewater Engineering, McGraw Hill, New York, 1972, pg. 231.

TABLE 12. INFLUENT, EFFLUENT, THICKENER SUPERNATANT AND VACUUM FILTRATE CHARACTERISTICS - MEDFIELD - PHASE 1

$\bar{x}$ = Mean Values
s = Standard Deviations

Characteristics	Influent		Effluent		Thickener Supernatant		Vacuum Filter Filtrate	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
COD-Total, mg/l	276	78	19	6.1	26	4.4	358	118
COD-Soluble, mg/l	87	23	17	5.8				
BOD_5-Total, mg/l	141	22	3.6	2.2	4.4	3.7	120	
BOD_5-N Suppressed, mg/l	93	24	1	0.6	0.7		101	
TOC, mg/l	75	10	13	16	12	3.5	91	19
Total Solids, mg/l	446	64	336	27	329	20	768	114
Total Volatile Solids, mg/l	185	43	78	25	71	12	381	84
Suspended Solids, mg/l	108	56	4.0	1.8	1	1.9	83	26
Volatile Susp. Solids, mg/l	85	48	2.8	1.5	1	1.9	55	19
Total Kjeldahl-N, mg/l	26	3.3						
Ammonia-N, mg/l	13	1.7	0.2	0.2				
Nitrate-N, mg/l	0	0	7.2	0.7				
Total Phosphorus, mg/l	10.6	3.7	0.7	0.1				
Grease, mg/l	74	72	4.5	0.7				
pH	7.1	0.2	7.3	0.1				
Temperature, °C	18	1.0	19	1.5				
Alkalinity, mg/l as $CaCO_3$	136	11.6						
Metals, mg/l								
Cadmium	0.04	0.02	0.03	0.03	0.03	0.03	0.02	0.03
Chromium	0.20	0.28	0.15	0.14	0.01	0.02	0.08	0.08
Copper	0.13	0.03	0.06	0.01	0.07	0.03	0.15	0.04
Nickel	0.10	0.04	0.10	0.07	0.09	0.01	0.10	0.09
Lead	0.59	0.10	0.15	0.09	0.45	0.53	0.23	0.20
Zinc	0.37	0.28	0.22	0.19	0.23	0.22	1.31	1.40

Effluent Quality Prior to Septage Addition

Medfield produces an exceptionally clear, low solids, low BOD_5 effluent. Average characteristics of secondary effluent produced by the plant are shown on Table 12. The tabulated values reflect effluent quality prior to tertiary sand filtration and chlorination. During Phase 1 the plant removed 97% of the influent BOD_5, 93% of the COD, and 96% of the suspended solids. Effluent quality and plant performance were exemplary.

Sodium aluminate is added prior to final clarification for phosphorus removal. Total phosphorus concentrations are normally kept below 1 mg/l, in accordance with regulatory requirements, and, during Phase 1, averaged 0.7 mg/l.

Heavy metal concentrations in effluent wastewater were below influent levels, and were consistent with metal quantities incorporated into the vacuum filter cake. (Table 12). Effluent and influent metal concentrations were within recommended drinking water standards.

Figure 8 shows low ammonia-N levels during the entire Phase 1 period. The ammonia nitrogen curve indicates that ammonia was completely converted to nitrates during the no-septage load period, except for a slight increase in ammonia concentration during the brief initial period, when the remnants of a clean-out operation were still in the system. Several days before the Phase 1 study was initiated, septage stored in the plant aerated grit chamber was fed to the plant. Complete conversion of ammonia to nitrate is expected in a system carrying 4,570 mg/l of mixed liquor volatile suspended solids, with an 88 day cell residence time. Under these conditions the growth rate of heterotrophic organisms is comparatively low, below the maximum growth rate of autotrophic nitrifying bacteria. This enabled the existence of nitrifiers in sufficient concentration to completely oxidize ammonia in the wastewater. As a comparison, treating an influent containing 26 mg/l of total kjeldahl nitrogen in a carbon oxidation-nitrification system (single stage activated sludge or extended aeration), ammonia break-through in the effluent would be expected when the cell residence time is reduced to about 5 days.[7] The growth rate of Nitrosomonas and the extent of nitrification in a system is dependent not only upon the growth rate of heterotrophic organisms, but also upon environmental factors--principally, dissolved oxygen, pH, temperature and alkalinity. During the entire monitoring period at Medfield, pH remained between 6.8 and 7.2, and temperature averaged 19°C. These conditions are excellent for growth. Alkalinity in the

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[7] Process Design Manual for Nitrogen Control, U.S. Environmental Protection Agency, Technology Transfer, 1975, pp. 3-17.

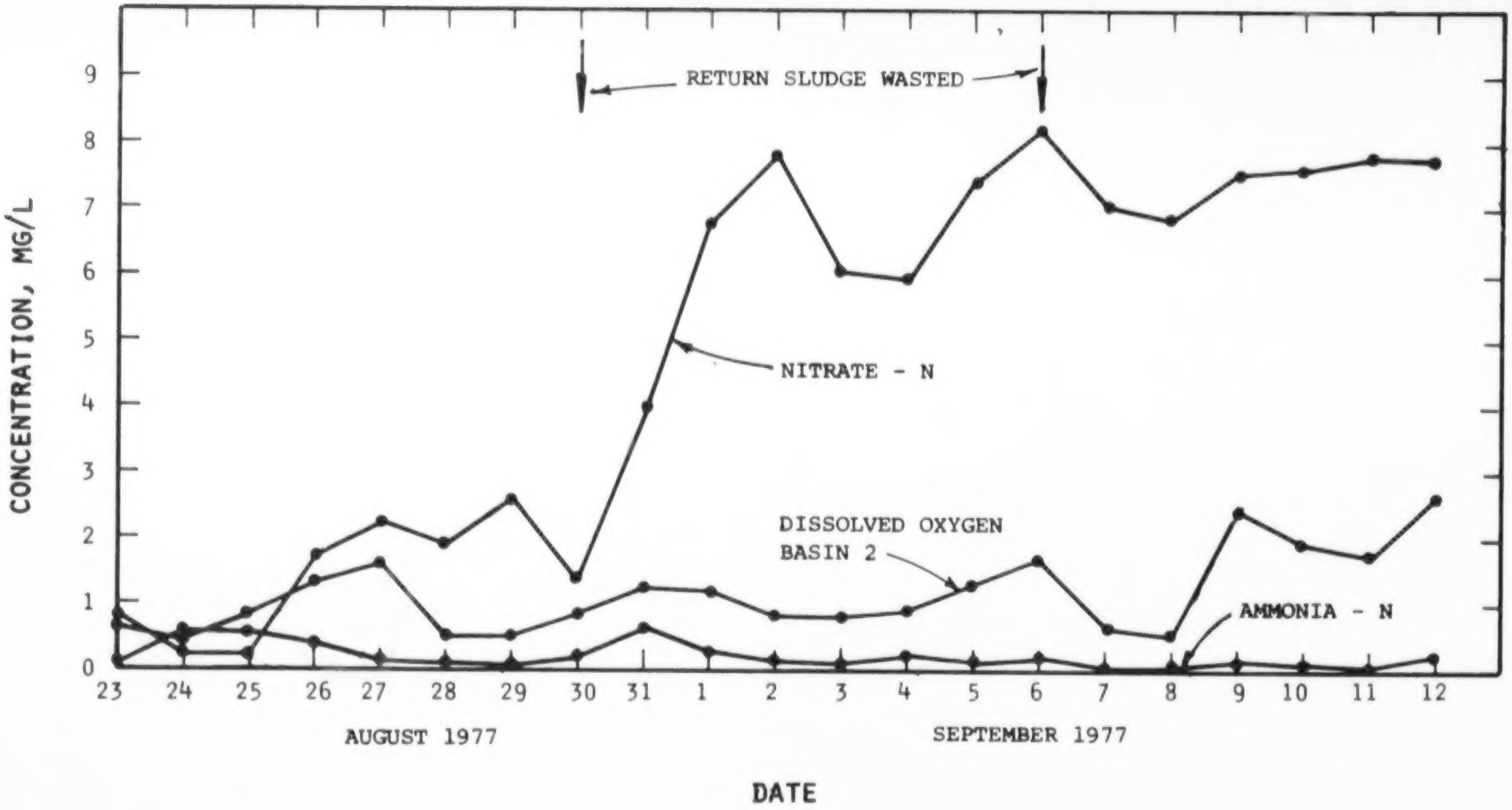

Figure 8. Effluent nitrogen and Basin 2 dissolved oxygen - Medfield - Phase 1.

influent wastewater was always sufficient for the synthesis of bacterial cells. However, dissolved oxygen in the aeration basins and the final clarifier were quite low--often well below 2 mg/l. Septage addition prior to the initiation of Phase 1 may have depressed dissolved oxygen levels sufficiently for the slight rise in ammonia shown in Figure 8 between August 24 and August 28. Dissolved oxygen, pH, temperature, and alkalinity values are shown on Appendix Table B-3.

The effect of dissolved oxygen on nitrification has been modeled using the Monod relationship:

$$\mu_N = \hat{\mu}_N \frac{DO}{K_{O_2} + DO}$$

where μ_N = Nitrosomonas growth rate, day $^{-1}$

$\hat{\mu}_N$ = peak Nitrosomonas growth rate, day $^{-1}$

DO = dissolved oxygen, mg/l

K_{O_2} = half-saturation constant for oxygen, mg/l

With a value of 1.3 assumed for K_{O_2}[8], the rate of ammonia conversion would be 43% of the peak rate at 1 mg/l, and 28% and 13% at 0.5 mg/l and 0.2 mg/l, respectively.

The following equation for bacterial synthesis and ammonia oxidation shows the relative quantities of ammonia converted either to nitrifiers or oxidized to nitrates:

$$NH_4^+ + 1.83O_2 + 1.98HCO_3^- \rightarrow 0.021C_5H_7NO_2 + 1.041H_2O + 0.98NO_3^- + 1.88H_2CO_3$$

The equation shows the relative unimportance of autotrophic synthesis in removing ammonia from a system. However, heterotrophic synthesis utilizes considerably more nitrogen. Cell yield (kg of mixed liquor volatile suspended solids produced under aeration per kg of BOD_5 removed) averaged 0.4 during Phase 1. This value is based upon BOD_5 reductions from 141 mg/l in the influent to 4 mg/l in the secondary effluent, and sludge production equal to 43 kg/day (95 lb/day) on a dry weight basis.

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[8] Process Design Manual for Nitrogen Control, U.S. Environmental Protection Agency, Technology Transfer, 1975, pp. 3-12.

assuming cell nitrogen content equal to 14%[9], nitrogen incorporations into heterotrophic cells would utilize 7.7 mg/l of available ammonia nitrogen from solution. Clearly, the fate of the remaining 15 to 18 mg/l of ammonia removed during Stage 1 was a transformation to nitrates.

Denitrification routinely occurs at Medfield and is associated with low dissolved oxygen in the aeration tanks and the final clarifier. Figure 8 shows nitrate nitrogen increasing from negligible concentrations at the initiation of testing to about 2 mg/l at the end of a week, increasing rapidly to 8 mg/l in a three day period, followed by values between 6 mg/l and 8 mg/l for the balance of the period. Increases in the conversion of nitrates to nitrogen gas and subsequent loss to the atmosphere generally coincides with decreasing dissolved oxygen levels. A comparison of dissolved oxygen levels in basin 2 and nitrate levels in the effluent shows this relationship.

A year after the completion of Phase 1 at Medfield, the plant was revisited on July 24, 1978. Nitrate concentrations were measured in three aeration basin compartments and in the final clarifier. The effluent NO_3-N concentration from basins 1, 2 and 4 were 3.6 mg/l, 1.5 mg/l and 0.65 mg/l, respectively. Dissolved oxygen levels in basins 2, 3 and 4 were between 0.8 and 1.5 mg/l near the surface, and essentially absent near the bottom of the tanks. Water temperature and plant loading were about the same as during Phase 1. Clearly, the plant nitrifies in the first aeration basin and denitrifies to some extent in the remainder of the basins.

Mixed Liquor and Secondary Sludge

Average mixed liquor characteristics, $\bar{x}$, are shown in Table 13. Standard deviations, s, in recorded data are also listed. High total solids concentrations maintained during Phase 1 and throughout the experimental period at Medfield caused nitrification and denitrification, by reducing the heterotrophic growth rate, and by keeping mixed liquor oxygen levels low.

Dissolved oxygen uptake was determined on samples taken from basin 3, chosen as an average value location. Low measured uptake values, an average of 15 mg/l/hr, were a result of the low F/M ratio. A disadvantage of maintaining high mixed liquor solids was increased air requirements. However, the two speed surface aerators used at Medfield give little flexibility for reducing aerator power consumption.

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[9] Schroeder, Edward D., Water and Wastewater Treatment, McGraw Hill, Inc., New York, 1977, pg. 182.

TABLE 13. MIXED LIQUOR AND SECONDARY SLUDGE CHARACTERISTICS MEDFIELD - PHASE 1

Characteristic	Mixed Liquor		Secondary Sludge	
	$\bar{x}$	s	$\bar{x}$	s
Total Solids, mg/l	7910	263	9830	1979
Total Volatile Solids, mg/l	4670	219	5850	1262
Suspended Solids, mg/l	7580	271		
Volatile Suspended Solids, mg/l	4570	214		
pH	7.0	.11		
Temperature, °C	20	1.2		
Alkalinity, mg/l as $CaCO_3$	241	34		
D.O. Uptake, mg/l-hr	15.0	5.5		
Dissolved Oxygen Basin #1, mg/l	4.7	1.2		
Dissolved Oxygen Basin #2, mg/l	1.2	0.6		
Dissolved Oxygen Basin #3, mg/l	1.0	0.6		
Dissolved Oxygen Basin #4, mg/l	1.0	0.6		
Dissolved Oxygen Clarifier, mg/l	1.2	0.6		
Settlometer, 30 min	695	71	803	47
Capillary Suction Time, sec			9.1	0.6

Settlometer test results are given in Appendix Table B-3. Samples for this analysis were taken from the end of aeration basin 4. Only small variations in values were observed during Phase 1. The mixed liquor settled slowly, sweeping material from suspension, and producing a clear supernatant.

Secondary clarifier sludge was returned to aeration basin 1 at an average rate of 0.018 cu m/sec (0.42 mgd) or twice the average influent flow rate. At this high return rate, solids buildup was minimal in the clarifier; total solids in the return sludge averaged 9,830 mg/l. While this value is comparatively high for extended aeration plant operation, it is not much greater than the mixed liquor concentration.

Sludge Dewatering

Thickener supernatant and vacuum filter filtrate were returned to the head end of the plant weekly during Phase 1. Chemical characteristics of these liquids are shown on Table 12. The thickener produced an extremely high quality supernatant.

Filtrate from the vacuum filter was high in organic content - on a par with strong domestic sewage; but the small quantity produced had little impact on secondary treatment. Table 14 shows solids concentrations in thickener sludge and vacuum filter cake. Nalco type 7120 liquid polymer was used both in the thickening and dewatering processes. The coil-spring filters produced cake containing about 12% solids. This relatively wet cake is characteristic of polymer treatment. Total solids wasted during Phase 1 averaged 185 kg/day (407 lb/day). Volatile solids were 60% of the total.

TABLE 14. THICKENER SLUDGE AND VACUUM FILTER CAKE - MEDFIELD - PHASE 1

Parameter	Thickener Sludge	Vacuum Filter Cake
Total Solids, percent	5.6	12.2
kg/day		185
(lb/day)		(407)
Total Volatile Solids, percent	3.4	7.4
kg/day		115
(lb/day)		(253)
Volume, cu m/day	5.36	
(gal/day)	(1420)	
Capillary Suction Time, sec	12.1	
Metals, mg/kg dry cake		
Cadmium		38
Chromium		306
Copper		1240
Nickel		179
Lead		1330
Zinc		1080

A solids balance for Phase 1 is shown on Table 15. The table shows average results obtained on three days during Phase 1, when solids were wasted: August 30, September 6, and September 15. The August 30 wasting contained septage solids discharged prior to the Phase 1 period. The difference between total volatile solids input and output is biological sludge production. This difference, Y_{obs}, was 43 kg/day (95 lb/day) or 0.4 kg of mixed liquor volatile suspended solids produced per kg of BOD_5 removed.

TABLE 15. VOLATILE SUSPENDED SOLIDS BALANCE
MEDFIELD - PHASE 1

Sample	Volatile Suspended Solids	
	Input	Output
Influent, kg/day	66	
(lb/day)	(146)	
Septage, kg/day	8	
(lb/day)	(17)	
Change in MLVSS in Basin, kg/day	0	0
(lb/day)	(0)	(0)
Secondary Effluent, kg/day		2
(lb/day)		(5)
Cake, kg/day		115
(lb/day)		(253)
Biological Sludge Production kg/day	43	
(lb/day)	(95)	
Totals, kg/day	117	117
(lb/day)	(258)	(258)

The observed yield coefficient reflects bacterial decay as well as production. The observed coefficient, Y_{obs}, is related to a growth-yield coefficient, Y, that depicts growth only by:

$$Y_{obs} = \frac{Y}{1 + k_d \theta_c}$$

where

k_d = microorganism-decay coefficient, time $^{-1}$

θ_c = mean cell residence time = SRT

Utilizing the kinetic decay coefficients for aerobic treatment of domestic wastes, $k_d = 0.05$ days $^{-1}$, and the actual Phase 1 mean cell residence time, $\theta_c = 88$ days, and computed observed yield coefficient, $Y_{obs} = 0.4$, gives a growth yield coefficient, Y, of 2.16. This value exceeds reported Y values (0.5 kg of MLVSS produced/kg BOD_5 removed) by a factor of four. It is probable that the 88 day cell retention time used for this computation overestimates the effective retention time under aerobic conditions. Low dissolved oxygen in aeration basins 2, 3 and 4 resulted in comparatively low time of solids under aeration.

PHASE 2 - CONTINUOUS FEEDING

Process Characteristics

Process characteristics for the continuous septage feed studies, Phases 2A and 2B, are shown on Table 16. The baseline data are included for comparison. Continuous feeding was approximated by introducing small quantities of septage every 15, 30 or 60 minutes throughout a test period.

During Phase 2 influent sewage flow increased slightly over the average Phase 1 rate, causing slightly lower aeration basin hydraulic retentions and lower Q_r/Q values. During Phase 2A, the plant was fed septage at a rate equal to 2% of the average sewage flow, on a volumetric basis. The organic loading to the plant doubled: loading increased from 83.3 to 152 gm BOD_5/cu m-day (5.2 to 9.5 lb BOD_5/1000 cu ft - day). This Phase 2A value is at the low end of a range of organic loadings experienced at extended aeration plants (see Table 11). Solids wasting was increased during Phase 2, and as a result, mixed liquor volatile suspended solids did not increase above Phase 1 levels. The combination of increased organic loading and constant mixed liquor solids concentrations is reflected in the F/M ratio, which doubled.

In Phase 2B the feed rate was 3.6% of the sewage flow rate. This resulted in a three-fold increase in organic loading and F/M ratio. Organic loading during Phase 2B was near the upper limit of values normally experienced at extended aeration plants, but because of high solids retention in the aeration basins, the F/M ratio was considerably below conventional values. Mean cell residence time for Phase 2 also reflects high mixed liquor solids retention.

Influent Sewage and Septage

Sewage characteristics changed little throughout the Phase 1 - Phase 2 period. Average values for sewage shown on Tables 17 and 18 are similar to values shown for Phase 1 on Table 12. Daily variability, represented by standard deviations presented in Table 17 and 18, were considerably greater than differences in average values shown for each phase. Based upon these influent data, Phase 1 is considered a valid baseline for an appraisal of the effects of septage addition in Phase 2.

Septage characteristics are also shown on Table 17 and 18, as are the computed combined sewage and septage characteristics.

TABLE 16. PROCESS CHARACTERISTICS AND LOADING - MEDFIELD - PHASES 1 & 2

Characteristic	Phase 1	Phase 2A	Phase 2B
Flow Rate, Q, cu m/day	780	893	1,094
(mgd)	0.206	0.236	0.289
Septage Feed Rate, cu m/day	0	17.8	39.4
(gpd)	0	4,700	10,400
Septage/Sewage, percent	0	2.0	3.6
Sludge Return Rate, Qr, cu m/sec	0.018	0.017	0.020
(mgd)	0.420	0.398	0.457
Qr/Q	2.0	1.7	1.6
Aeration Basin Retention, hrs	37.6	32.2	25.9
Mixed Liquor Susp. Solids, mg/l	7,580	7,610	7,670
Mixed Liquor Volatile Susp. Solids, mg/l	4,570	4,610	4,770
F/M, kg BOD_5/kg MLVSS-day	0.018	0.033	0.055
BOD_5, kg/day	110	217	279
(lb/day)	(242)	(478)	(614)
COD-Total, kg/day	215	508	1005
(lb/day)	(474)	(1120)	(2215)
COD-Soluble, kg/day	68	137	161
(lb/day)	(149)	(301)	(355)
Total Solids, kg/day	348	508	968
(lb/day)	(766)	(1120)	(2135)
Total Volatile Solids, kg/day	144	241	609
(lb/day)	(318)	(532)	(1343)
Loading, gm BOD_5/cu m-day	83.3	152	245
(lb BOD_5/1000 cu ft-day)	(5.2)	(9.5)	(15.3)
Mean Cell Residence, days	88	59	36

The computed concentrations are based upon average daily flow rates and average characteristics of both sewage and septage. Septage variability is well documented and is discussed in Section 1. Storage at the plant tended to attenuate wide fluctuations in organic and solids concentrations, but it also diminished the strengths of the stored septage due to solids sep-

TABLE 17. SEWAGE AND SEPTAGE - MEDFIELD - PHASE 2A

Characteristic	Sewage		Septage		Combined Sewage and Septage*
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$
COD-Total, mg/l	308	118	13,190	13,500	558
COD-Soluble, mg/l	118	53	1,750	1,340	150
BOD_5-Total, mg/l	155	54	4,450	3,780	238
BOD_5-N Suppressed, mg/l	115	34	3,460	3,070	180
TOC, mg/l	71	8.0			
Total Solids, mg/l	448	75	6,110	3,530	558
Total Volatile Solids, mg/l	189	64	4,110	2,370	265
Suspended Solids, mg/l	114	77	4,580	3,120	201
Volatile Susp. Solids, mg/l	86	53	3,380	2,210	150
Total Kjeldahl-N, mg/l	26	4.0	213	65	30
Ammonia-N, mg/l	15	2.5	73	21	16
Nitrate-N, mg/l	0	0	0	0	0
Total Phosphorus, mg/l	11	2.6	127	50	13
Grease, mg/l	61	35	4,340	2,980	144
pH	7.0	0.2	6.9	0.4	7.0
Temperature, °C	17	1.1	18	2.2	17
Alkalinity, mg/l as $CaCO_3$	145	14	515	219	152
Metals, mg/l					
Cadmium	0.02	0.01	0.05	0.02	0.02
Chromium	0.12	0.03	0.60	0.43	0.13
Copper	0.22	0.10	4.17	2.61	0.30
Nickel	0.18	0.08	0.29	0.13	0.18
Lead	0.20	0.15	0.88	0.50	0.21
Zinc	1.65	3.12	4.62	2.84	1.71

*Calculated from sewage and septage quality data and relative proportions of each waste

aration. This occurred in the primary tank used for storage as well as in the grit chamber. Nevertheless, by purposely obtaining strong septage at Medfield, a moderately strong liquid was fed during Phase 2. Septage COD averaged about 13,000 mg/l in Phase 2A and 16,000 mg/l in Phase 2B. It is interesting to note that soluble COD was a small fraction of the total--about 10%

TABLE 18. SEWAGE AND SEPTAGE - MEDFIELD - PHASE 2B

Characteristic	Sewage		Septage		Combined Sewage and Septage
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$
COD-Total, mg/l	308	98	16,100	14,500	887
COD-Soluble, mg/l	106	67	1,080	410	142
BOD$_5$-Total, mg/l	122	39	3,510	3,300	246
BOD$_5$-N Suppressed, mg/l	77	22	1,800	674	140
Total Solids, mg/l	414	78	12,440	15,590	855
Total Volatile Solids, mg/l	210	58	9,140	11,320	538
Suspended Solids, mg/l	100	94	11,140	15,360	505
Volatile Susp. Solids, mg/l	86	69	8,300	11,130	388
Total Kjeldahl-N, mg/l	24	4.8	278	233	33
Ammonia-N, mg/l	16	3.3	69	6.3	18
Nitrate-N, mg/l	0.6	0.1			
pH	7.3	0.3	7.2	0.3	7.3
Temperature, $^{\circ}$C	15	0.5	12	1.0	15
Alkalinity, mg/l as CaCO$_3$	136	15	665	187	155
Metals, mg/l					
Cadmium	0.05	0.07	0.06	0.03	0.05
Chromium	0.07	0.01	0.27	0.23	0.08
Copper	0.08	0.01	2.43	1.40	0.16
Nickel	0.04	0.03	0.26	0.18	0.05
Lead	0.26	0.12	1.40	0.57	0.30
Zinc	0.23	0.06	5.51	4.01	0.41

for both periods. This result is consistent with the operation of septic tanks, in which soluble organics are displaced into a leaching field, while the major liquid fraction pumped from tanks is recent influent sewage. Association of organic content with suspended solids was observed in the majority of septage samples. However, some septage samples were encountered, during the course of the study, that were comparatively clear, but yielded surprisingly high COD values.

Septage solids data shown in Tables 17 and 18 are consistent with the COD data. Septage volatile suspended solids averaged 86% of the total volatile solids. These results suggest that primary clarification should be an effective process for septage solids separation from a combined sewage/septage influent to a municipal plant. In fact, this result is confirmed by studies at Barnstable, Massachusetts[10] and by our research at Marlborough, presented in Section 6 of this report.

In comparison with sewage, septage nutrient/carbon ratios are low, but not below levels that tend to inhibit bacterial growth. BOD_5:N:P ratios for sewage and septage at Medfield were 13.3:2.5:1 and 35:1.7:1, respectively. Nitrogen is TKN-N, and phosphorus is total phosphorus. The combined septage and sewage had a BOD_5:N:P relationship of 18.3:2.3:1. These values are well within growth limiting ratios of about 60:3:1.[11]

Septage brought to Medfield contained considerable quantities of grease. In Phase 2A the 2% input of septage more than doubled the grease load on the plant. Septage had little effect on pH, alkalinity, or metal concentrations at Medfield. Comparison of sewage and combined influent on Tables 17 and 18 show only negligible increases in concentrations.

Phase 2 data are presented in detail in Appendices C and D. The reader is encouraged to review the data in total as a means of gaining insights into the impact of septage on this treatment facility, which plots and statistical parameters do not provide.

Effluent Quality

Changes in effluent quality caused by the continuous addition of septage are shown on Table 19. Total and soluble COD average values appear to increase with septage addition. BOD_5, total solids, suspended solids, and volatile suspended solids data suggest that septage at the 2% and 3.6% levels did not affect effluent quality. Only the average total volatile solids for Phase 2B appears higher than baseline values. On September 23, the return sludge pumps at Medfield were inadvertently turned off over night. This caused a reduction in mixed liquor suspended solids shown on Appendix Table C-4 and increased solids and organic concentrations in the secondary effluent. Data that reflect the effects of this malfunction are not included in the average values shown on Table 19. To determine if septage actually increased effluent organic concentrations, one-way analysis-of-variance tests were conducted on data shown in Appendices B-2, C-3 and D-3. Phase 1 was compared with Phase 2A and 2B data. The results of these computations are shown in Table 20.

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[10] Guttenplan, Steven D.,"The Establishment of a Septage Receiving and Handling Program for the Town of Barnstable, Mass.", Journal of the New England Water Pollution Control Association, Part 1, Volume II, 1977, pp. 1-10.

[11] Clark, N.W., Viessman, W., and Hammer, M.J., Water Supply and Pollution Control, International Textbook Co., Toronto, 1971, pg. 269.

TABLE 19. EFFLUENT QUALITY -
MEDFIELD - PHASES 1 & 2

Characteristic	Phase 1	Phase 2A		Phase 2B	
	$\bar{x}$	$\bar{x}$	s	$\bar{x}$	s
COD-Total, mg/l	19.5	27	11	31	5.0
COD-Soluble, mg/l	17	20	7.3	26	7.4
BOD_5-Total, mg/l	4	3.7	2.7	2.5	1.0
BOD_5-N Suppressed, mg/l	1	1.0	0.9	1.4	0.8
TOC, mg/l	13	6.3	4.2		
Total Solids, mg/l	336	326	45	316	68
Total Volatile Solids, mg/l	78	68	22	115	42
Suspended Solids, mg/l	4	3.2	2.7	2.4	1.4
Volatile Susp. Solids, mg/l	3	2.0	1.9	2.1	1.4
Ammonia-N, mg/l	0.2	2.7	2.0	0.4	0.2
Nitrate-N, mg/l	7.2	4.1	3.5	12.8	1.8
Total Phosphorus, mg/l	0.7	1.4	0.7		
Grease, mg/l	4.5	3.9	0.6		
pH	7.3	7.1	0.3	7.4	0.3
Temperature, ^oC	19	18	1.3	14.1	0.9
Heavy Metals, mg/l					
Cadmium	0.03	0.02	0.01	0.01	0.01
Chromium	0.15	0.13	0.04	0.05	0.04
Copper	0.06	0.14	0.09	0.03	0.01
Nickel	0.10	0.11	0.01	0.01	0.01
Lead	0.15	0.03	0.05	0.08	0.02
Zinc	0.22	0.70	1.40	0.41	0.46

The observed F ratio for total COD is larger than the critical value of F at the 99% level. The assumption that septage addition did not increase the concentrations of organic material in secondary effluent cannot be rejected. Analysis-of-variance computations for the solids data support the contention that the effluent was not affected, with the exception of the Total Vola-

TABLE 20. ANALYSIS OF VARIANCE RESULTS - MEDFIELD

Parameter	Computed F	F_{99}**	Degrees of Freedom	
			k-1*	n_i-1**
COD-Total	7.61	5.12	2	45
COD-Soluble	4.98	5.12	2	45
BOD_5-Total	0.99	5.40		29
BOD_5-N Suppressed	0.69	5.15	2	44
Total Solids	0.65	5.10	2	49
Total Volatile Solids	8.83	5.11	2	48
Suspended Solids	2.04	5.10	2	49
Volatile Suspended Solids	1.88	5.10	2	49

* k = the number of data groups (3 in all cases)

** n_i = total number of measurements

** Dixon and Massey, Introduction to Statistical Analysis, (McGraw Hill, New York) :398.

tile Solids results (and this result is based only upon Phase 2B data). There was no significant difference between Phase 1 and Phase 2A total volatile solids values.

If septage affected effluent quality during continuous feeding at 2% and at 3.6%, the effects were barely measureable. It is concluded that septage did not diminish effluent quality. Statistically, the long periods of monitoring, particularly Phase 2A, provide an adequate basis for this conclusion. Effluent quality was well within regulatory requirements. Grease and heavy metal concentrations in the effluent were unaffected by septage addition.

Nitrogen

Ammonia and nitrate concentrations varied during Phase 2 in response to septage loading, aeration basin dissolved oxygen levels, bacterial population response, and changes in mixed liquor volatile suspended solids concentration. The latter was dependent upon sludge production and wasting. Figures 9 and 10 show ammonia nitrogen and nitrate nitrogen concentrations as a function of time. In Phase 2A the aerator in basin 1 was on high; the remaining aerators in basins 2, 3, and 4 were kept on the low setting. During Phase 2B, the aerators in basins 1 and 2 were on high; the remainder on low.

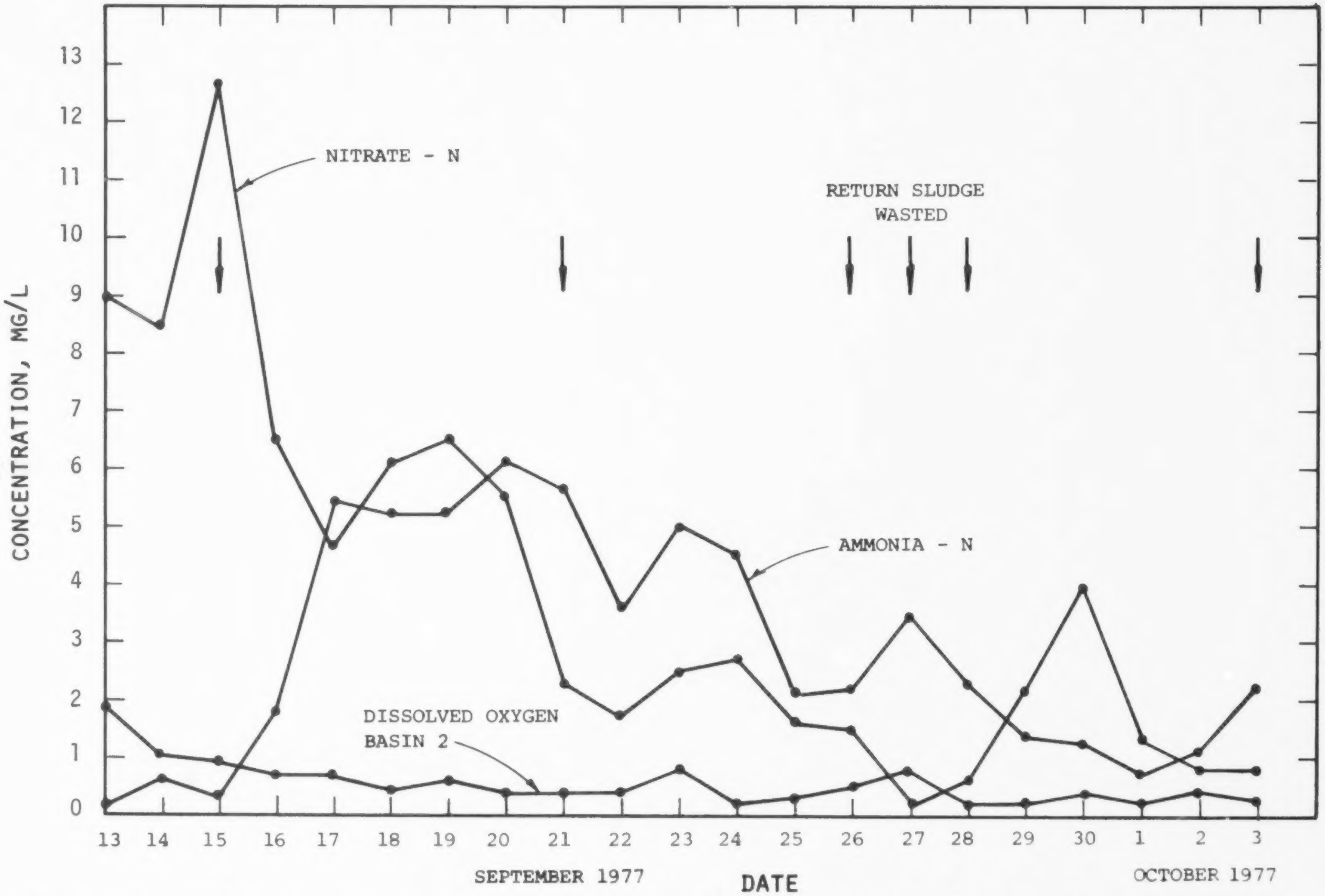

Figure 9. Effluent nitrogen and Basin 2 dissolved oxygen - Medfield - Phase 2A.

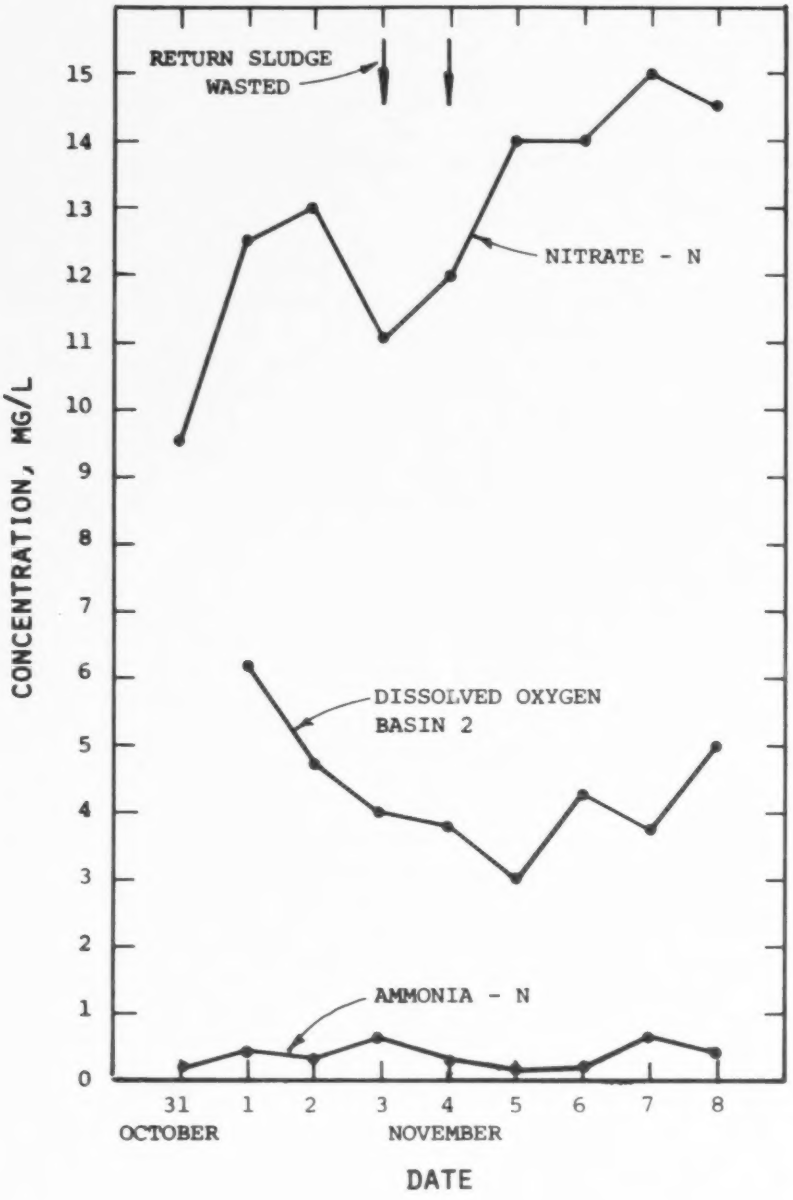

Figure 10. Effluent nitrogen and Basin 2 dissolved oxygen - Medfield - Phase 2B.

In Phase 2A the ammonia began to increase in the plant effluent three days after initiation of loading. It reached a maximum of 6.1 mg/l as N, three days later, and declined thereafter. Throughout this phase of monitoring, nitrification was never complete. The three day period prior to the initial increase provided sufficient time for a process response to the impact of increased organic loading. The initial rise also coincides with solids wasting on September 15. Similar responses do not occur on other wasting days. Apparently, wasting did not significantly reduce nitrifying bacterial populations.

Nitrate nitrogen concentrations in secondary effluent declined steadily during Phase 2A from levels above 8 mg/l during the first several days of loading, to less than 1 mg/l near the end of the test period. Denitrification exhibited in Phase 2A is associated with dissolved oxygen levels in basins 2, 3, and 4. Dissolved oxygen in basin 2 declined steadily from 1.9 mg/l on September 13 to 0.45 mg/l six days later on September 19. Thereafter, dissolved oxygen was very low or nonexistent in basins 2, 3, and 4. Dissolved oxygen values during this period are shown on Appendix Table C-4.

Phase 2B was conducted one month after completion of 2A. During the intervening month, the plant was shock loaded with a slug of septage (Phase 3A). During the week of continuous loading, Phase 2B, the plant nitrified completely. This was accomplished at almost twice the previous loading.

Nitrification and Denitrification - An Explanation

While nitrification was essentially completed in the first aeration basin during Phase 1, increased organic loading in Phase 2 apparently inhibited nitrification in this basin. During Phase 2A the nitrifiers were further inhibited in basins 2, 3, and 4 by low dissolved oxygen levels; nevertheless, considerable ammonia oxidation did occur. In Phase 2B increased oxygen input to basin 2 (high aerator setting) increased dissolved oxygen levels in basins 2, 3, and 4. This is shown on Figure 10 and in Appendix Table D-5. Figure 10 shows the results of increased dissolved oxygen in basins 2, 3, and 4 - complete nitrification demonstrated by low ammonia concentrations and a marked reduction in denitrification, shown by high nitrate levels.

Phosphorus

In Phase 1 phosphorus averaged 10.6 mg/l in the influent sewage (See Table 21). This was equivalent to an input of 8.3 kg/day (18.2 lb/day). The addition of 48.1 l/day (12.7 gal/day) of a 19% solution of sodium aluminate, 9.1 kg/day (20.1 lb/day), as Al_2O_3 reduced phosphorus in the effluent to 0.7 mg/l, 0.5 kg/day (1.2 lb/day). Approximately 1.2 kg of sodium aluminate were used per kg of phosphorus removed in the processes.

TABLE 21. PHOSPHORUS REMOVAL MEDFIELD - PHASES 1 & 2

	Phase 1 kg/day	(lb/day)	Phase 2A kg/day	(lb/day)
Influent	8.3	(18.2)	10.0	(22.1)
Septage			2.3	(5.0)
Effluent	0.54	(1.2)	1.3	(2.9)
Phosphorus Removed	7.8	(17.0)	11.0	(24.2)
Al_2O_3 Used	9.1	(20.1)	10.3	(22.8)
Al_2O_3/P, kg/kg*	1.2		0.94	
Al_2O_3/P, kg/kg**	1.5		1.13	
Al^{+++}/P, kg/kg**	0.79		0.60	

*Based upon total phosphorus removal

**Assuming 2 mg/l P incorporation into cells, BOD/P≈90/1

Assuming 2 mg/l of phosphorus taken up by organisms based upon a 90:1, C:P ratio in sludge[12], the ratio of Al_2O_3 to phosphorus precipitated increases to 1.5 or 0.79 as Al^{+++}:P. This compares with estimates of 0.87 as Al^{+++}:P.[13]

In Phase 2A, phosphorus derived from septage and a higher sewage flow increased input to the plant to 11.0 kg/day. During this phase of operation sodium aluminate feed was insufficient, and effluent phosphorus concentrations averaged 1.5 mg/l. Again, assuming 2 mg/l cell uptake, Al_2O_3:P, and Al^{+++}:P ratios were 1.13 and 0.60, respectively. These values are lower than both Phase 1 and reported values, and are a direct result of the high effluent concentrations, i.e., the remaining fraction of phosphorus would require proportionally more aluminate for removal.

Based upon an average of 190 mg/l of phosphorus in septage, 0.23 kg of Al_2O_3 are required per cu m of septage (0.39 lb/1000 gal). For commercially available sodium aluminate solution (19% Al_2O_3), 1.2ℓ of sodium aluminate solution is required per cu m of septage (1.2 gal/1000 gal).

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[12] Fair, Geyer and Okun, Water and Wastewater Engineering, Wiley, New York, 1968, pp. 34-6.

[13] Process Design Manual for Phosphorus Removal, U.S. Environmental Protection Agency, Technology Transfer, 1971, pp.3-4.

Dissolved Oxygen

Sludge wasting during Phase 2 compensated for septage solids, either added with septage or produced in the aeration basins from the soluble septage fraction. Table 22 shows mixed liquor solids concentrations and alkalinity unchanged throughout Phase 1 and Phase 2. Basal metabolism oxygen requirements are thus assumed constant for the period, and changes in oxygen demand are attributed to septage addition.

TABLE 22. MIXED LIQUOR CHARACTERISTICS - MEDFIELD - PHASES 1&2

Characteristic	Phase 1	Phase 2A		Phase 2B	
	$\bar{x}$	$\bar{x}$	s	$\bar{x}$	s
Total Solids, mg/l	7910	8050	369	7990	263
Total Volatile Solids, mg/l	4670	4750	249	4880	143
Suspended Solids, mg/l	7580	7720	354	7770	238
Volatile Susp. Solids, mg/l	4570	4670	241	4780	138
pH	7.0	6.9	0.3	7.3	0.4
Temperature, °C	20	18	1.7	14.2	0.8
Alkalinity, mg/l as $CaCO_3$	241	241	30	225	70
D.O. Uptake, mg/l-hr	15.0	20.6	5.8	13.5	4.2
Dissolved Oxygen Basin #1, mg/l	4.7	3.5	1.1	2.0	1.4
Dissolved Oxygen Basin #2, mg/l	1.2	0.5	0.4	3.6	1.1
Dissolved Oxygen Basin #3, mg/l	1.0	0.5	0.3	2.9	1.1
Dissolved Oxygen Basin #4, mg/l	1.0	0.5	0.4	2.3	1.1
Dissolved Oxygen Clarifier, mg/l	1.2	0.5	0.4	1.1	1.0
Settlometer, 30 min	695	705	41	439	40

Dissolved oxygen levels in the aeration basin were affected by septage loading and aerator setting. In basin 1 dissolved oxygen dropped from an average of 4.7 mg/l, in Phase 1, to 3.5 in Phase 2A and finally to 2.0 mg/l in Phase 2B. During Phase 1 basins 2, 3, 4 and the clarifier held an average of 1 mg/l of dissolved oxygen. However, with the same aerator settings these basins just barely held their dissolved oxygen during Phase 2A. Basins 2, 3, and 4 would not have remained aerobic in Phase 2B had the basin 2 aerator stayed on the low setting.

Based upon dissolved oxygen and temperatures in basin 1, computations using the expression:

$$\frac{dO_2}{dt} = K(C_s - C)$$

show a 37% increase in oxygen utilization in basin 1 between Phase 1 and Phase 2A, and a 90% increase between Phase 1 and Phase 2B, where:

$\frac{dO_2}{dt}$ = rate of oxygen utilization, mg/l-day

K = oxygen transfer coefficient, day^{-1}

C_s = oxygen saturation concentration, a function of temperature, mg/l

C = measured dissolved oxygen concentrations, mg/l

A 13% increase was observed in basins 2, 3, and 4 in Phase 2A.

Dissolved oxygen uptake measured directly in basin 3 increased by 37% in Phase 2A from an average of 15.0 mg/l-hr to 20.6 mg/l-hr. In Phase 2B dissolved oxygen uptake averaged 13.3 mg/l-hr in basin 3 and 16.7 in basin 1. These values are comparable to the Phase 1 average uptake rates.

It is apparent that the principal BOD_5 fraction was exerted in the first two basins and that measured uptake rates in basin 3 do not reflect this demand. This is particularly true in Phase 2B with increased air input to basin 2. Measured dissolved oxygen uptake values in basin 1 are time dependent and vary as a surge of sewage or septage enters the basin. Dissolved oxygen levels attenuate these effects and are a better indication of oxygen utilization.

Using dissolved oxygen levels, the information included in Table 23, and the following equation, oxygen utilization was computed for the septage added in Phase 2A.

$$\left[\frac{dO_2}{dt}\right]_{II} - \left[\frac{dO_2}{dt}\right]_{I} = \frac{dO_2}{dt} = K\left[(C_s - C)_{II} - (C_s - C)_{I}\right]$$

$$\text{kg } O_2/\text{kg } BOD_5 = \frac{dO_2}{dt}/BOD_5 = K\left[\frac{(C_s - C)_{II} - (C_s - C)_{I}}{BOD_5}\right]$$

where,

BOD_5 = BOD_5 in septage added in Phase 2A (plus the slight

TABLE 23. DISSOLVED OXYGEN UTILIZATION - MEDFIELD - PHASES 1 & 2

					Phase 2B					
					Pre-loading & Recovery Period			During Test		
	Phase 1		Phase 2A							
Basin #	1	2, 3&4	1	2, 3&4	1	2	3&4	1	2	3&4
Dissolved Oxygen, C, mg/l	4.7	1.0	3.1	0.5	4.6	5.3	4.2	1.6	3.4	2.4
Saturation D.O., Cs, mg/l	9.1	9.1	9.5	9.5	10.2	10.2	10.2	10.3	10.3	10.3
$\frac{dO_2}{dt}$, kg/day			87.4	39.3				134.4	87.4	83.0
$\frac{dO_2}{dt}$, kg/day			26.7	36.1				41.1	26.7	50.8
ΔBOD (Difference Phases 1 & 2) kg/day			106					138		
kg O_2/kg BOD_5			0.59					0.86		
Δ COD (Phase 1-2)			284					626		
kg O_2/kg COD			0.22					0.19		
kg O_2/kw-hr	1.22		1.42		0.67			0.94		
lb O_2/hp-hr	2.01		2.33		1.10			1.55		

increase due to increased sewage inflow)

$(C_s - C)_I$ = dissolved oxygen deficit in Phase 1.

The reaeration coefficient K was calculated from Phase 1 oxygen uptake measurements and equals 43.7 day^{-1}.

Based upon dissolved oxygen deficits in the four aeration basins, dissolved oxygen utilization attributed to the incremental septage load was 0.59 kg O_2/kg BOD_5. The Phase 1 oxygen utilization for sewage was 4.5 kg O_2/kg BOD_5, but most of this was for cell respiration.

If the five-day biochemical oxygen demand value, BOD_5, for septage is assumed to be 68% of the ultimate demand BOD_L, then oxygen utilization was 0.4 kg O_2/kg BOD_L. The 68% is an average value for domestic sewage and has not been verified for septage.

The turbine aerators at Medfield are rated at 7.46 kw (10hp) at 1800 rpm (high setting) and 1.86 kw (2.5 hp) at 900 rpm (the low setting). The four units produced an average of 1.2 kg O_2/kWh(2.0 lb O_2/hp-h) during Phase 1 and 1.4 kg O_2/kWh (2.3 lb/hp-h) during Phase 2A. This compares with design values for activated sludge processes between 1.5 kg O_2kWh (2.5 lb O_2/hp-h) and 2.4 kg O_2/kWh (4.0 lb O_2/hp-h).[14]

Oxygen utilization for Phase 2B could not be determined by comparison with Phase 1 because of the change in speed of the basin 2 aerator. For Phase 2B a comparison was made between average dissolved oxygen levels during loading and values obtained just prior to and following the loading period. This analysis yielded values of 0.74 kg O_2/kg BOD_5 and 0.9 kg O_2/kWh (1.6 lb O_2/hp-h).

In conclusion, it appears that conventional oxygen requirements and transfer design parameters used for the treatment of domestic sewage at extended aeration plants may be applied to the treatment of sewage and septage. Conventional parameters are conservative for the Medfield operation.

Thickener Supernatant and Vacuum Filtrate Quality

Organics and solids concentrations in flotation thickener supernatant did not increase with septage addition. A comparison is shown on Table 24. Supernatant quality with or without septage addition was similar to secondary effluent. Increases in heavy metals concentrations shown on Table 24 are attributed to sample variation and the limited data base. Unless septage is derived from industrial sources, concentrations of metals in thickener supernatant, vacuum filter filtrate or sludge cake should not change appreciably with septage addition.

Table 25 shows an increase in vacuum filtrate organic and solids concentrations between Phase 1 and Phase 2. An analysis-of-variance of filtrate and supernatant data indicates no significant difference between Phase 1, Phase 2A and Phase 2B data. However, the statistical analysis is based upon a small number of samples.

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[14] Schroeder, Edward D., Water and Wastewater Treatment, McGraw Hill, New York, 1977, pg. 115.

TABLE 24. THICKENER SUPERNATANT CHARACTERISTICS MEDFIELD - PHASES 1 & 2

Characteristic	Phase 1	Phase 2A		Phase 2B	
	$\bar{x}$	$\bar{x}$	s	$\bar{x}$	s
COD-Total, mg/l	26	25	5.2	35	3.2
BOD_5-Total, mg/l	4.4	1.4	0.6	4.5	2.4
BOD_5-N Suppressed, mg/l	0.7	1.3	0.9	2.1	0.3
TOC, mg/l	12				
Total Solids, mg/l	329	313	21	303	32
Total Volatile Solids, mg/l	71	51	14	71	20
Suspended Solids, mg/l	1	8.6	12	7.0	7.8
Volatile Susp. Solids, mg/l	1	5.6	10	4.0	2.6
Metals, mg/l					
Cadmium	0.03	0.02	0.01	0.01	0.01
Chromium	0.01	0.51	0.64	0.05	0.03
Copper	0.07	0.16	0.12	0.03	0.01
Nickel	0.09	0.12	0.02	0.03	0.01
Lead	0.59	0.21	0.19	0.11	0.03
Zinc	0.23	1.21	0.98	0.28	0.02

Sludge Production

In Phase 1 the plant produced 185 kg/day (407 lb/day) of dry solids. The 2% septage addition increased production to 260 kg/day (571 lb/day) and the 3.6% addition increased it to 309 kg/day (679 lb/day). Total solids, volatile solids, and heavy metal concentrations are shown in Table 26.

Table 27 shows a volatile solids mass balance for Phase 2. Volatile solids production increased from 43 kg/day (95 lb/day) in Phase 1 to 77 kg/day (168 lb/day) in Phase 2A and to 143 kg/day (317 lb/day) in Phase 2B. The Phase 1 and 2A estimates are each based upon three weeks of data, while Phase 2B is based upon one week of data and a single wasting period. Thus the Phase 2A data are used for sludge production estimates.

Increases in the quantity of solids wasted daily from the plant are compared on Table 28 for Phase 2A with increases in organic and solids loading. There appears to have been a direct one-to-one relationship between the increase in BOD_5 and soluble COD, and volatile suspended solids production in the aeration basins. It also appears that the increase in septage and sewage total solids caused a corresponding rise in cake production.

TABLE 25. VACUUM FILTRATE CHARACTERISTICS
MEDFIELD - PHASES 1 & 2

Characteristics	Phase 1	Phase 2A		Phase 2B	
	$\bar{x}$	$\bar{x}$	s	$\bar{x}$	s
COD-Total, mg/l	358	970	600	1140	696
BOD_5-Total, mg/l	120	398	19	383	77
BOD_5-N Suppressed, mg/l	101	243	6.4	160	33
TOC, mg/l	71	143			
Total Solids, mg/l	768	1290	660	1390	815
Total Volatile Solids, mg/l	381	658	392	742	484
Suspended Solids, mg/l	83	1170	1440	918	760
Volatile Susp. Solids, mg/l	55	717	893	590	481
Metals, mg/l					
Cadmium	0.02	0.02	0.02	0.04	0.01
Chromium	0.08	0.19	0.06	0.08	0.01
Copper	0.15	0.30	0.22	0.55	0.42
Nickel	0.10	0.10	0.01	0.07	0.01
Lead	0.23	0.51	0.32	0.74	0.06
Zinc	1.31	1.70	1.18	1.36	0.97

Settlometer Tests

Settlometer tests in conjunction with mixed liquor and return sludge solids concentration analysis, sludge blanket depth measurements, and sludge volume index (SVI) determinations are used to regulate sludge return rates and sludge wasting. Process control using the "West" method requires the addition of a return sludge centrifuge test.[15]

Figure 11 is a characteristic plot of settled sludge volume as a function of settling time. Average curves for Phases 1 and 2 are shown. The level of mixed liquor solids carried at Medfield was atypical of extended aeration plants. As a result the settling was slow, compaction was limited and the average curves are considerably above conventional measurements. Settling improved slightly after each wasting period as shown on

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[15] Alfred W. West, Return Sludge Flow Control, (National Waste Treatment Center: U.S. EPA, September 1960).

TABLE 26. THICKENER SLUDGE AND VACUUM FILTER CAKE MEDFIELD - PHASES 1 & 2

	Thickener Sludge			Vacuum Filter Cake		
Phase	1	2A	2B	1	2A	2B
Total Solids, percent	5.6	4.6	4.0	12.2	12.0	11.8
kg/day				185	260	309
(lb/day)				407	571	679
Total Volatile Solids, percent	3.4	2.8	3.0	7.4	7.4	5.2
kg/day				115	164	270
(lb/day)				253	361	596
Volume, cu m/day	5.36					
(gal/day)	1420					
Capillary Suction Time, sec	12.1	14.7	7.0			
Metals, mg/kg dry cake						
Cadmium				38	22	33
Chromium				306	166	108
Copper				1240	792	735
Nickel				179	75	83
Lead				1330	389	622

TABLE 27. VOLATILE SUSPENDED SOLIDS BALANCE MEDFIELD - PHASE 2

	PHASE 2A		PHASE 2B	
Sample	Input	Output	Input	Output
Influent, kg/day	78		95	
(lb/day)	(172)		(209)	
Septage, kg/day	53		208	
(lb/day)	(118)		(458)	
Change in MLVSS, kg/day		42		174
(lb/day)		(93)		(384)
Secondary Effluent, kg/day		2		2
(lb/day)		(4)		(4)
Cake, kg/day		164		270
(lb/day)		(361)		(596)
Sludge Production kg/day	77		143	
(lb/day)	(168)		(317)	
Totals, kg/day	208	(208)	446	446
(lb/day)	(458)	(458)	(984)	(984)

TABLE 28 - SOLIDS RATIOS - MEDFIELD - PHASE 2A

	Ratio Phase 2A/Phase 1
Cake Solids Production	
Total Solids	1.41
Total Volatile Solids	1.43
Influent Sewage and Septage	
Total Solids	1.46
BOD_5	1.98
COD-Soluble	2.02
Sludge Production	
Mixed Liquor Volatile Suspended Solids	1.79

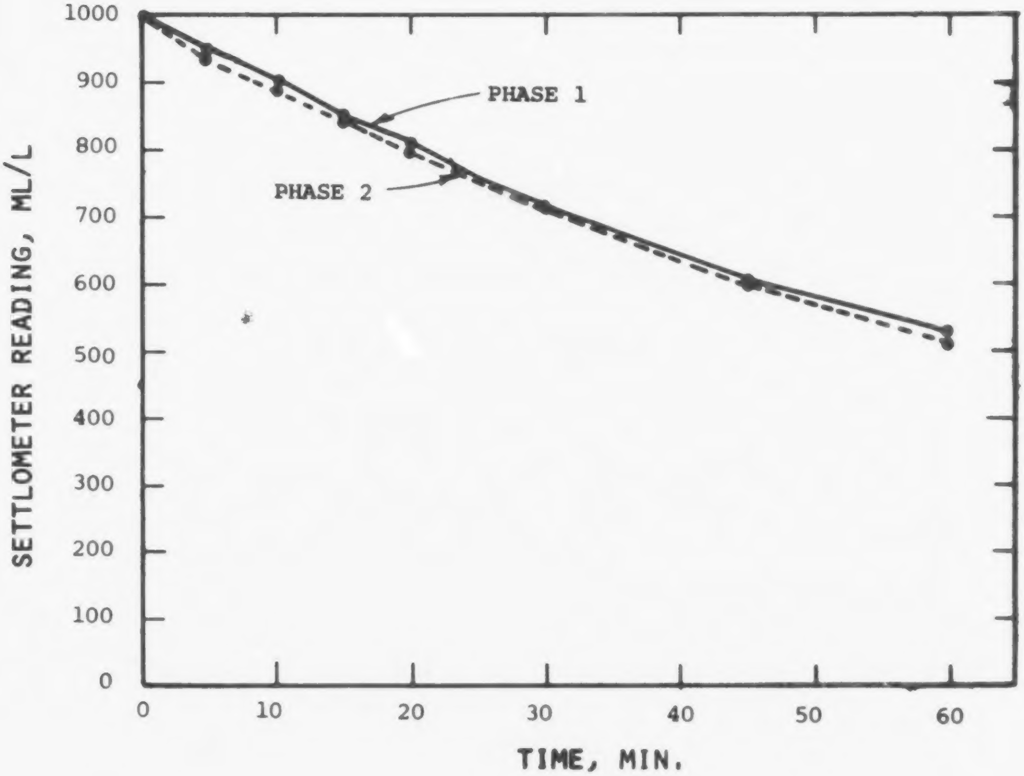

Figure 11. Settlometer Readings - Medfield - Phases 1 and 2.

Figures 12 and 13, but because of the high solids concentration, changes in settlometer readings were never a useful indication of meeting requirements.

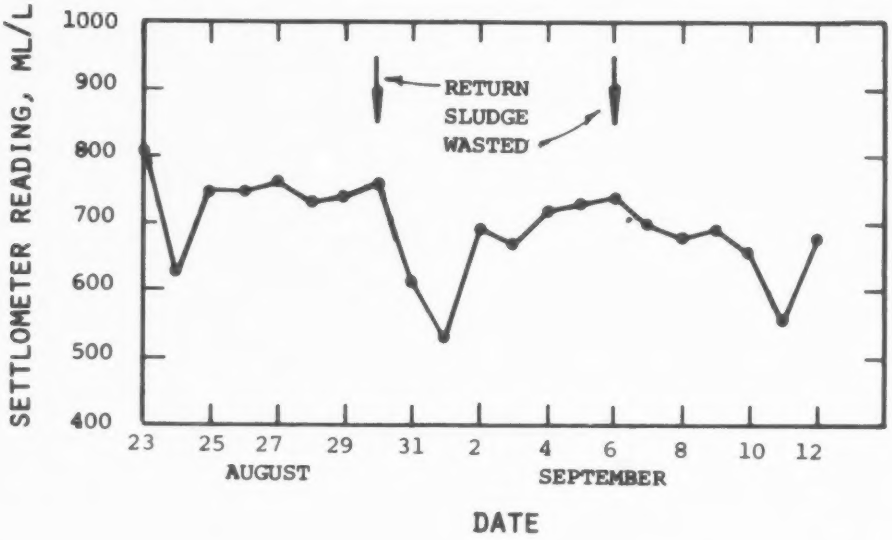

Figure 12. Mixed liquor 30-minute settlometer readings - Medfield - Phase 1.

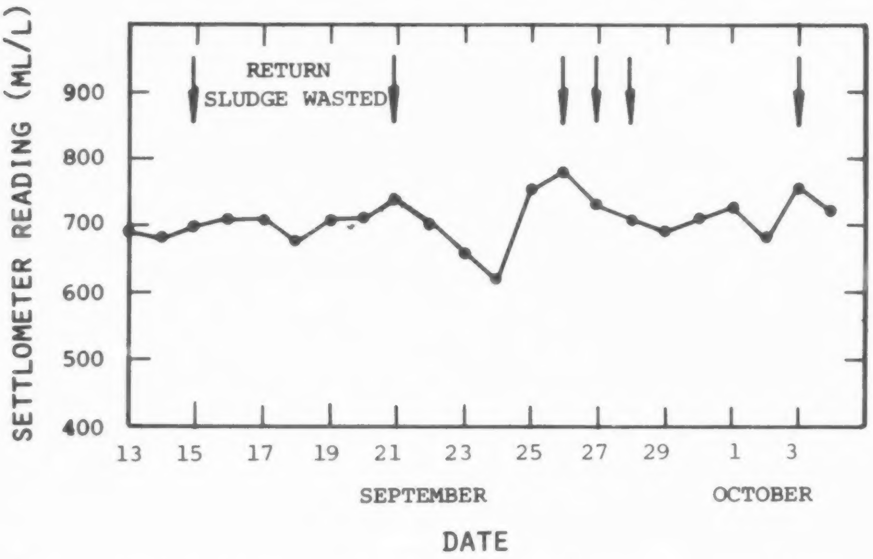

Figure 13. Mixed liquor 30-minute settlometer readings - Medfield - Phase 2A.

Sludge Dewatering

In Phase 2 solids fed to the thickener and vacuum filter increased in direct proportion to the total solids in the added septage. Septage addition resulted in increased polymer use, again, in proportion to the quantity of solids added. Vacuum filter cake was unaffected by septage addition but septage did reduce the percent of solids in the thickener float (See Table 26). This was caused by an increase in wasted sludge suspended solids concentration above Phase 1 levels. The average return sludge solids concentration on the wasting days was 10,850 mg/l in Phase 2 as compared with 8,970 mg/l in Phase 1. The increased solids caused a 17% reduction in the air to solids ratio which reduced the float solids content from 5.55% to 4.62%.[16]

Sludge dewatering was determined during Phase 1 and 2 by observing the cake produced weekly and by conducting Capillary Suction Time,CST, measurements on returned and thickened sludge. The measuring device was a Type 130 Triton CST apparatus. The device measures the dewaterability of sludges by monitoring the time it takes to extract a unit volume of water by capillary suction.

Samples of returned sludge collected prior to thickening in both phases had low CST values: this indicates excellent dewaterability. Individual measurements are plotted on Figure 14. The increase in solids in Phase 2 had no effect on CST values, nor did the nature of the sewage/septage mixture affect returned sludge CST.

Figure 14 also shows a reduction in thickened sludge CST values with increasing septage addition. This was probably a result of decreasing solids concentration. Whether or not septage improved sludge dewaterability is debatable--certainly it did not diminish dewaterability.

PHASE 3 - SHOCK LOADING

In Phase 3, the plant was slug loaded daily with quantities of septage which averaged 1.8% of the daily sewage flow rate during the first three-day test, and 2.6% during a second four-day test. The percent rate of septage feed based upon actual sewage and septage flow rates was 10-13% during Phase 3A and 60-75% during Phase 3B. The methods used to shock the plant were presented in a description of the monitoring program at Medfield (Section 4 of this report).

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[16] U.S. Environmental Protection Agency, Process Design Manual for Sludge Treatment and Disposal, 1974, pp. 4-21.

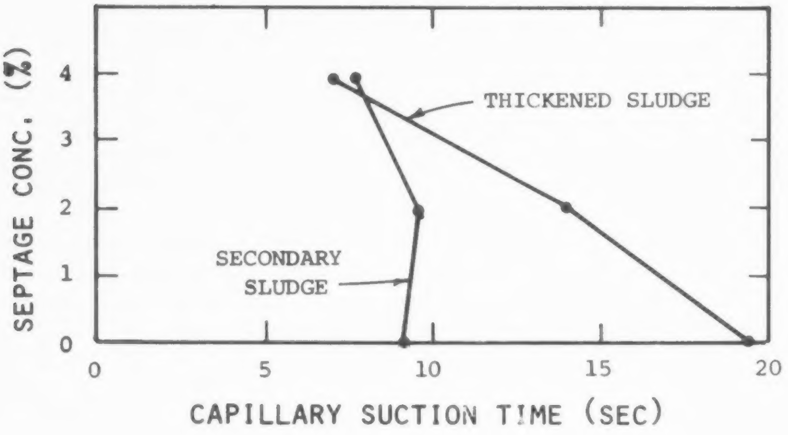

Figure 14. Septage feed vs. capillary suction time - Medfield.

Shock loading affected many aspects of the Medfield process: mixed liquor concentrations, protozoan growth, effluent quality, and particularly dissolved oxygen concentrations. Changes occurred quickly and recovery was rapid. The effects of each shock on the system are shown in detail in Appendices E and F.

Influent Sewage and Septage

Average influent sewage and septage characteristics during Phase 3 are shown on Table 29. Sewage flow into the plant increased 58% over the Phase 1 levels. The increase was primarily caused by storm water infiltration into the Medfield sewerage system. This conclusion is supported by a comparison of Phase 1 and Phase 3 COD, BOD_5 and solids data. The Phase 3 averages are considerably below Phase 1 levels. During Phase 3 the plant received about the same sewage solids and organic load as during Phase 1, but hydraulic detention times were reduced by 37%.

Strong septage was selected and transported to Medfield for the Phase 3 study. Analyses of material used for each test are included in the Appendices. Generally, the septage had a COD in the 28,000 mg/l range, BOD_5 of about 5,000 mg/l, and total solids, 14,000 mg/l. The exception was the third day of Phase 3A, when 37.9 cu m (10,000 gal) of septage sediment that had accumulated during the previous tests were pumped into the plant. This miasmic liquid had a COD of at least 60,000 mg/l.

Effluent Quality

Between 7 a.m. and 8 a.m. sewage flow sharply increased at Medfield, and remained comparatively high each morning. This is

TABLE 29. SEWAGE AND SEPTAGE CHARACTERISTICS

MEDFIELD - PHASE 3

Phase	Sewage 3A	Sewage 3B	Septage 3A	Septage 3B
Flow, cu m/day	1,240	1,220		
mgd	0.33	0.32		
Septage/Sewage			1.5-2.0	2.4-3.1
COD-Total, mg/l	191	230	39,400	27,200
COD-Soluble, mg/l		77	1,740	2,000
BOD_5-Total, mg/l	84	72	5,590	5,100
BOD_5-N Suppressed, mg/l	51	50	4,310	3,980
Total Solids, mg/l	387	386	12,800	14,100
Total Volatile Solids, mg/l	143	138	10,100	10,700
Suspended Solids, mg/l	89	87	11,000	12,870
Volatile Susp. Solids, mg/l	73	72	8,870	9,860
Total Kjeldahl-N, mg/l		21		400
Ammonia-N, mg/l	13	23	57	176
Nitrate-N, mg/l		0.6		
Total Phosphorus, mg/l	14		147	
pH	7.4		6.9	
Alkalinity, mg/l as $CaCO_3$	135	137	460	377
Temperature, °C		14		

a common occurrence at treatment plants. The effects of this surge of sewage were: a rise in the F/M ratio, increased dissolved oxygen uptake rates, lower D.O. in the aeration basins, and initially higher D.O. levels in the secondary clarifier. Flow from the clarifier abruptly increased. Initially, clarifier effluent organic content is low, reflecting extended treatment during the night. The increased flow shortens the hydraulic retention time during the morning hours, and results in diminished effluent quality late in the day. The effects of septage addition are viewed in light of this normal early morning fluctuation.

Changes in secondary effluent COD and BOD_5 during the two shock loading periods are shown on Figures 15 and 16. The BOD_5 data plotted on both of these figures show no definite increases associated with shock loading. The slight perturbation in these

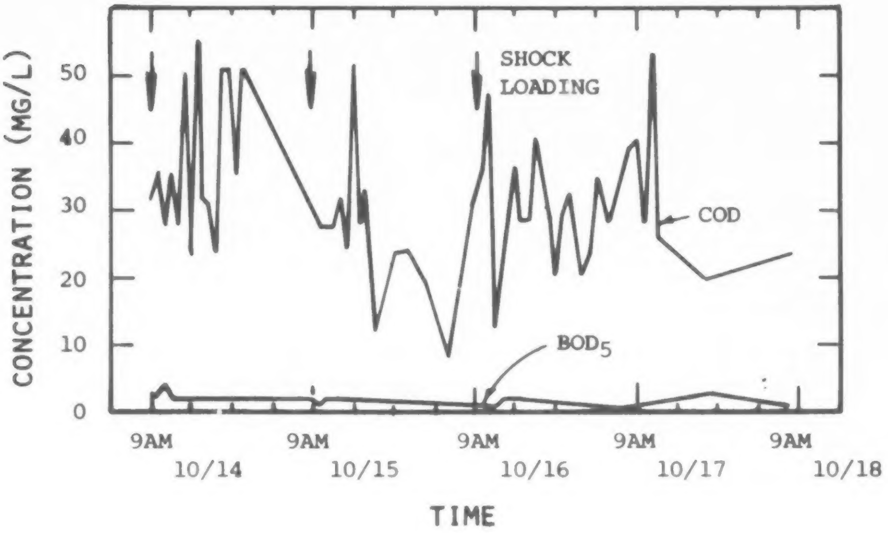

Figure 15. Effluent BOD and COD - Medfield - Phase 3A.

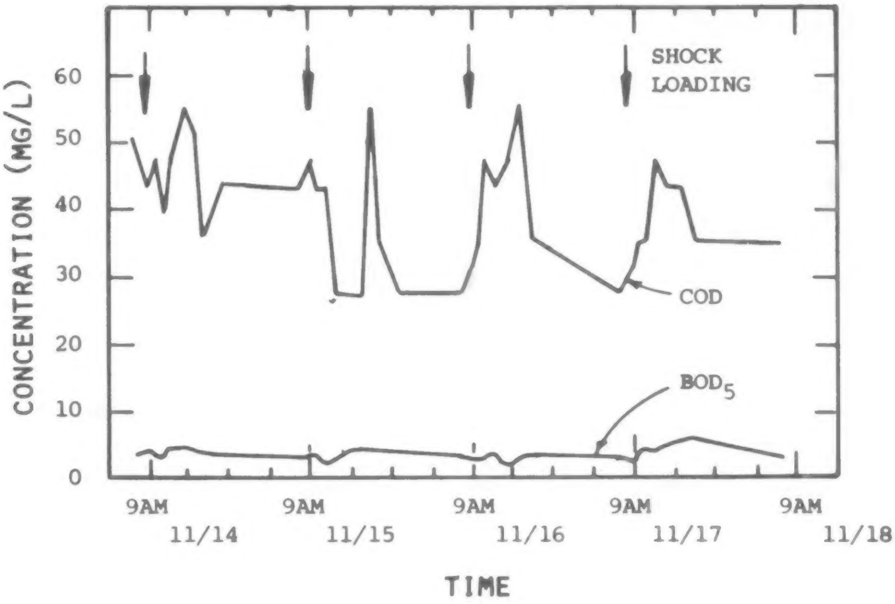

Figure 16. Effluent BOD and COD - Medfield - Phase 3B.

data appear to be random. Throughout the two periods, BOD_5 levels were at least as low as during Phase 1.

Phase 1 effluent total COD averaged 20 mg/l, and effluent soluble COD averaged 18 mg/l. During Phase 2, effluent total COD increased slightly to an average of 32 mg/l, and soluble COD increased to 24 mg/l. The overall effect of shock loading in Phase 3 was again a slight deterioration in effluent quality: total COD increased to about 32 mg/l in Phase 3A, and to 40 mg/l in 3B. Soluble COD data for Phase 3B averaged 23 mg/l.

Peak COD concentrations in Phase 3 generally occurred five to seven hours after the morning sewage surge and septage input. Recovery was rapid and a second increase in COD values was not observed after the early evening sewage flow surge, which was less pronounced.

Secondary effluent total and suspended solids data are plotted on Figure 17 and 18. In Phase 1 total and suspended solids in the effluent averaged 336 mg/l and 4.0 mg/l, respectively. Only total solids data following the first two shocks during Phase 3B (Figure 18) show values significantly above the Phase 1 levels.

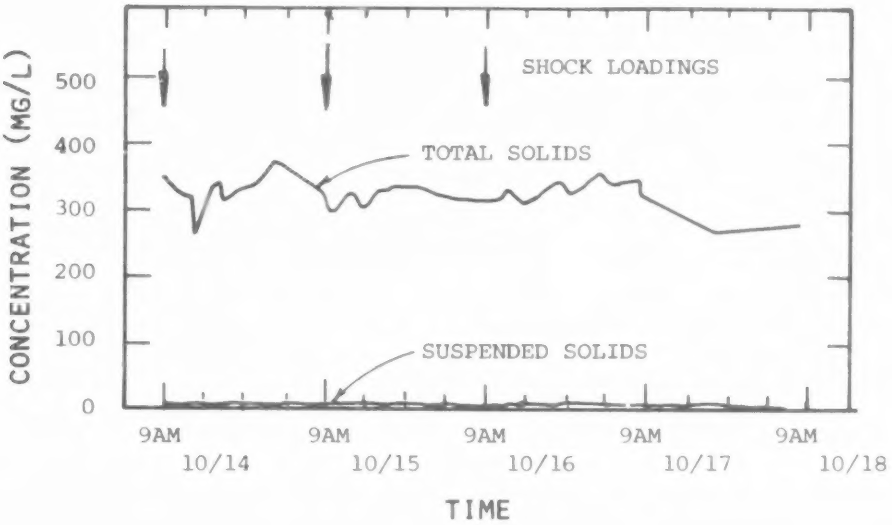

Figure 17. Effluent total solids and suspended solids - Medfield - Phase 3A.

The results of organic and solids analyses, just reviewed, indicate that secondary effluent quality was little affected by the introduction of comparatively large quantities of septage.

Increases in COD observed daily during Phase 3 were caused primarily by flow surges. It is suggested that had septage been added several hours before the morning surges, the impact upon effluent quality would have been more pronounced.

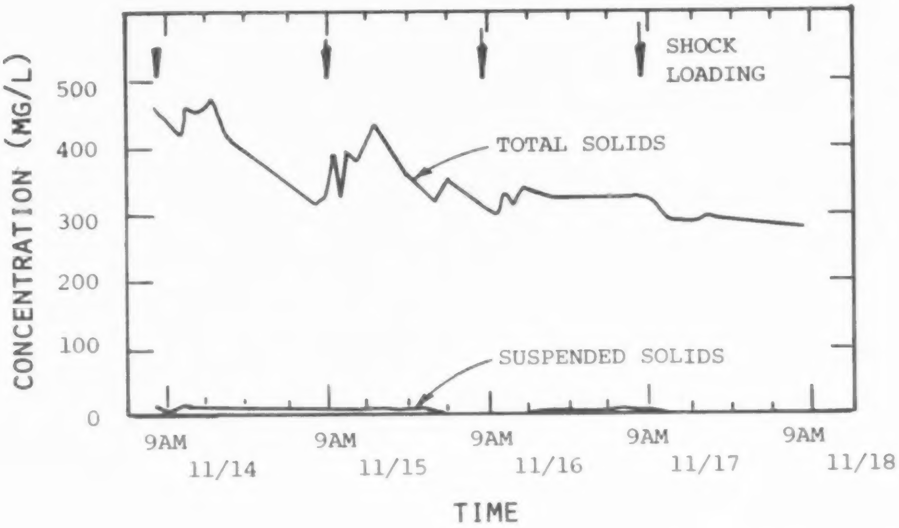

Figure 18. Effluent total solids and suspended solids - Medfield - Phase 3B.

Nitrogen

Ammonia data for Phase 3 are given in Appendix Tables E3 and F3. During Phase 3A, effluent ammonia nitrogen levels never exceeded 0.1 mg/l. During the three-day shock loading period, nitrate nitrogen levels steadily declined from 15 mg/l to 5 mg/l. Complete conversion of ammonia to nitrates occurred throughout the test period. Denitrification began on the second day, and was coincident with the drop in basin 2 dissolved oxygen levels. This is shown on Figure 19. The principal effect of the slug load was a rapid reduction in mixed liquor dissolved oxygen levels, which resulted in a gradual increase in nitrate reduction over the course of the test.

Nitrification and denitrification processes seen in Phase 3A were repeated in Phase 3B. The large quantities of septage used in Phase 3B only slightly inhibited nitrification. These data are plotted in Figure 20. Dissolved oxygen levels dropped dramatically after each shock load, and denitrification again increased steadily during the four-day period.

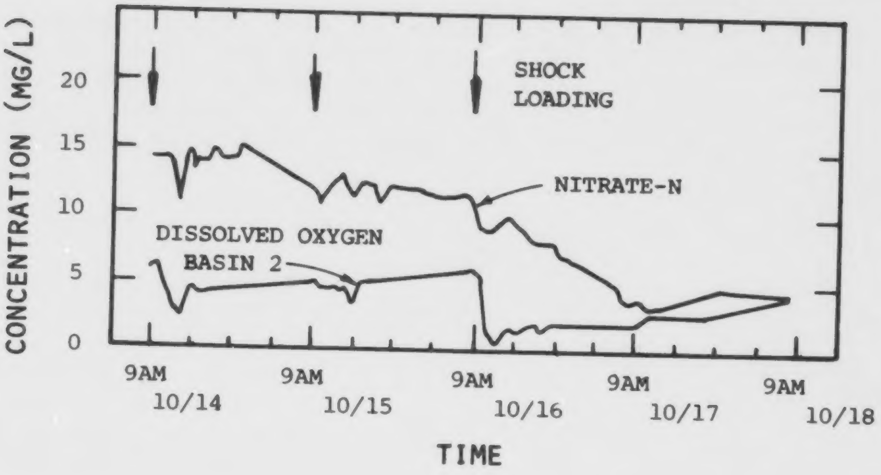

Figure 19. Effluent nitrogen and Basin 2 dissolved oxygen - Medfield - Phase 3A.

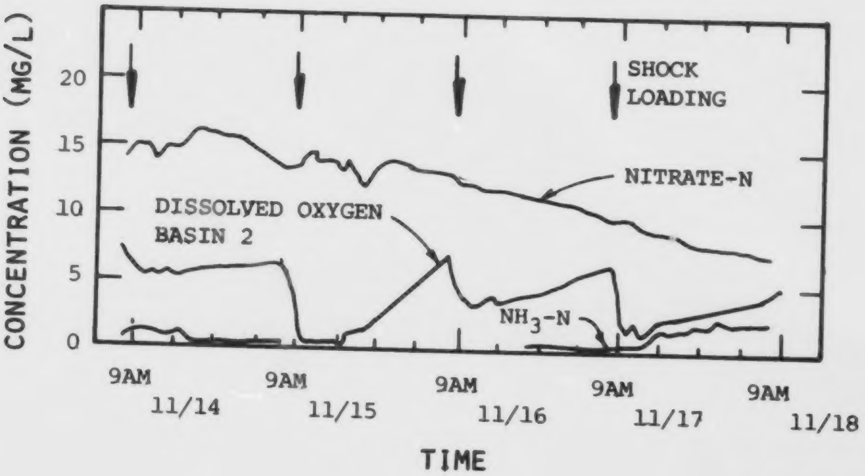

Figure 20. Effluent nitrogen and Basin 2 dissolved oxygen - Medfield - Phase 3B.

Dissolved Oxygen

The introduction of a large slug of septage caused an initial decline in basin 1 dissolved oxygen. The initial demand is the weighted average of the anaerobic slug diluted in the 302 cu m (80,800 gal) basin. Septage did not cause an initial mixed liquor dissolved oxygen reduction to a value less than given by:

$$D.O._{final} = \frac{D.O._{initial} \cdot VOL_{basin}}{VOL_{basin} + VOL_{septage}}$$

This was determined experimentally in the laboratory. For example, the 29.5 cu m (7,780 gal) of septage introduced on three days of Phase 3B caused an initial 9% drop in the pre-shock dissolved oxygen concentration. The major observed decline in oxygen levels was caused by a rapid increase in dissolved oxygen uptake.

Figures 21 and 22 show the rapid increase in dissolved oxygen uptake rates experienced after each shock loading. These curves vividly demonstrate the treatability of septage in systems treating domestic sewage. The effect of the shock load was most pronounced in the first aeration basin. Rates increased in Phase 3B, Figure 22, from 10 to 15 mg/l-hr to 25 to 45 mg/l-hr. The high uptake rates lasted for about six to eight hours and declined thereafter. On each day of the Phase 3 shock period, the uptake rate ascended to a higher value than on the previous day, and returned to a higher value preceding the next shock. The basin 3 data shown in Figures 21 and 22 show a two-hour lag in response to the shock loadings, and slighter increases than experienced in the first basin. Basins 1 and 2 obviously did the "lion's share" of the work.

Settling

Thirty-minute settlometer results for basins 1 and 4 are shown on Figures 23 and 24. In each case, septage solids increased the settling rate and markedly diminished supernatant quality. In Phase 3A thirty-minute settlometer readings changed from 650 ml/l to about 550 ml/l.

Average settlometer curves for the entire monitoring period are shown on Figure 25. Figure 25 is a plot of settled sludge volume as a function of time. Generally, the curves show that settling rates and sludge compaction increased with septage additions.

Values obtained after shock loading the plant with 29.5 cu m (7,780 gal) of septage on November 16, 1977 are shown on

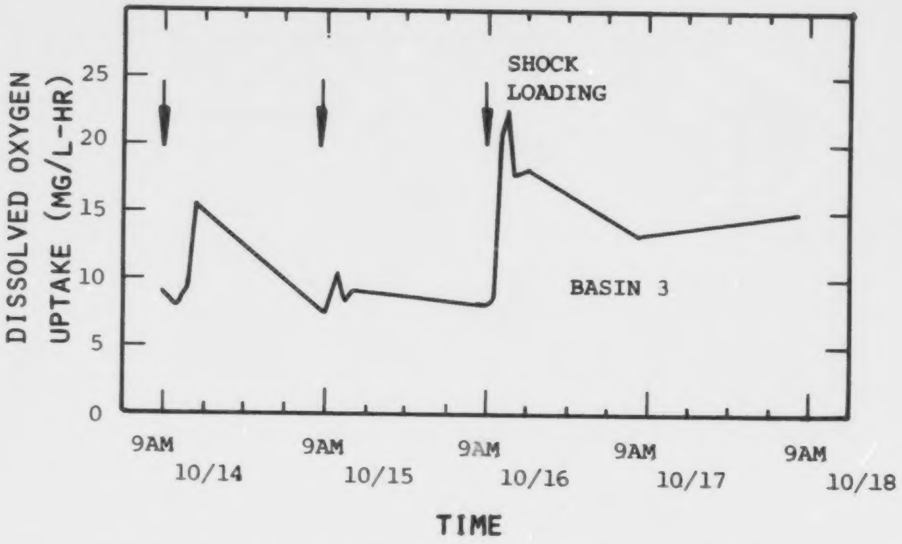

Figure 21. Basin 3 dissolved oxygen uptake - Medfield - Phase 3A.

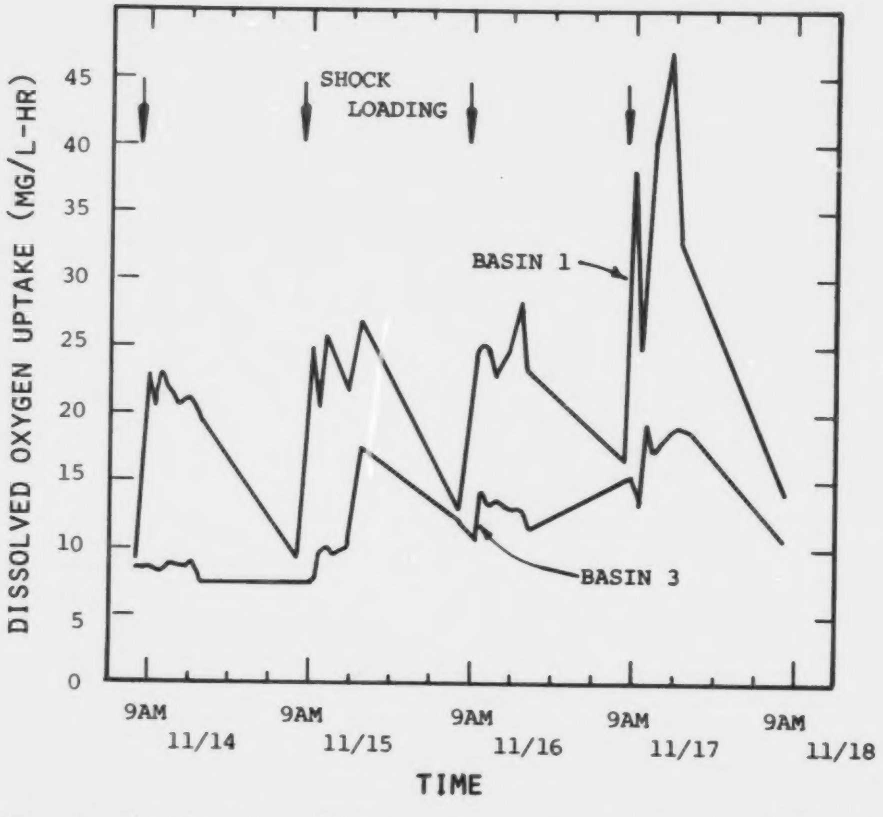

Figure 22. Basin 1 and 3 dissolved oxygen uptake - Medfield - Phase 3B.

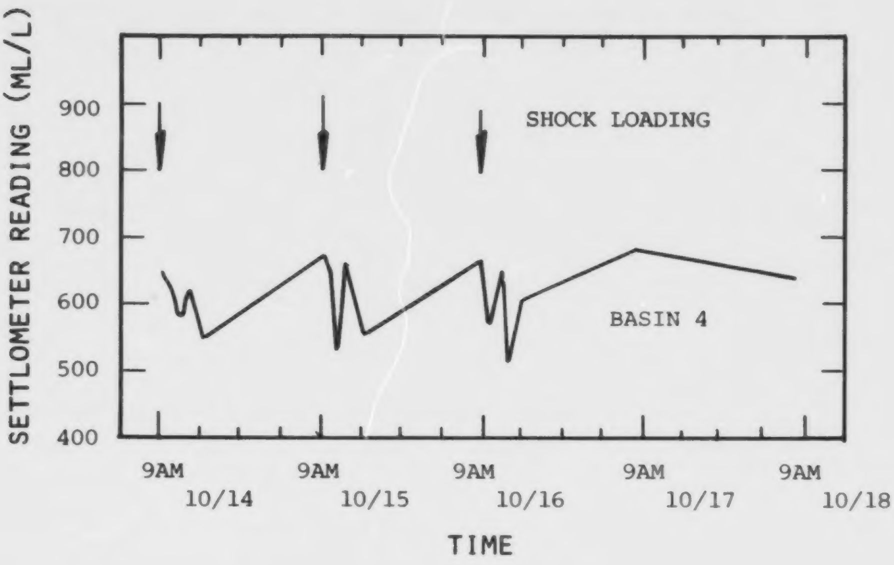

Figure 23. Thirty-minute settlometer reading Basin 4 - Medfield - Phase 3A.

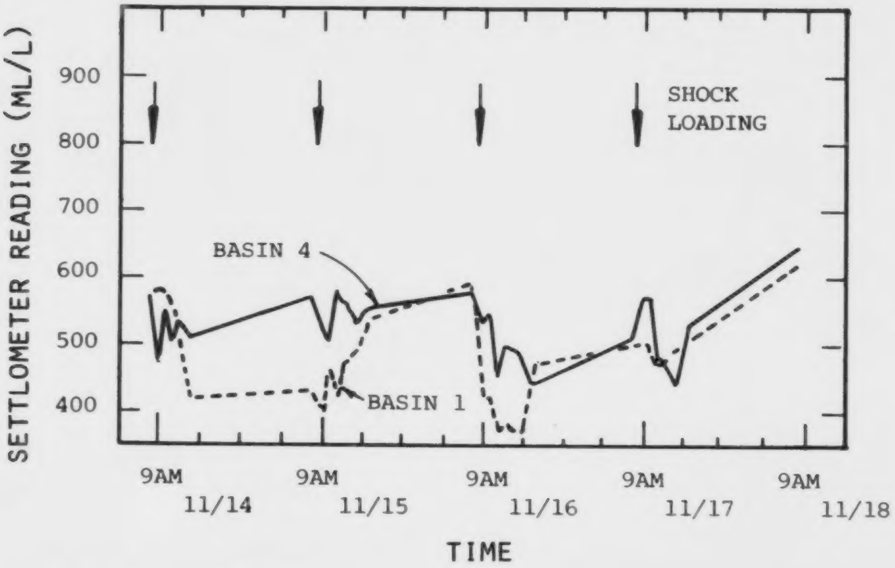

Figure 24. Thirty-minute settlometer reading Basins 1 and 4 - Medfield - Phase 3B.

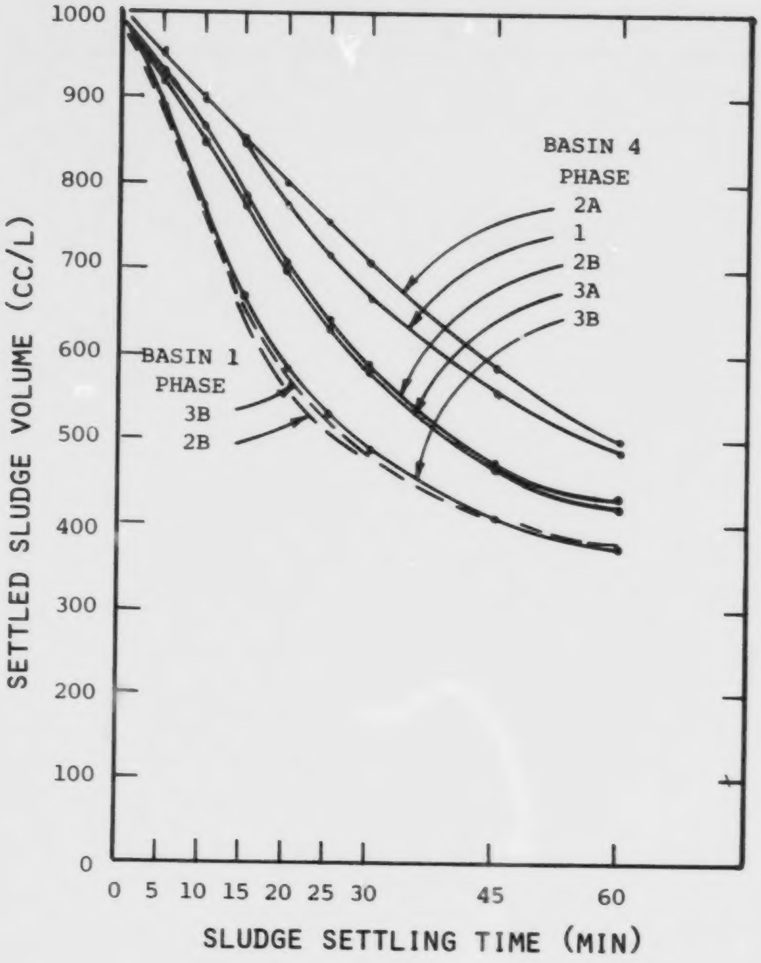

Figure 25. Average settlometer readings Basin 4 - Medfield.

Figure 26. Settlometer supernatant turbidity levels increased shortly after the shock loading for the sample taken from basin 1. A similar increase in turbidity occurred with the basin 3 sample after a lag period reflecting septage displacement through the aeration tanks. Deterioration in supernatant quality was visually apparent as septage was added to the system.

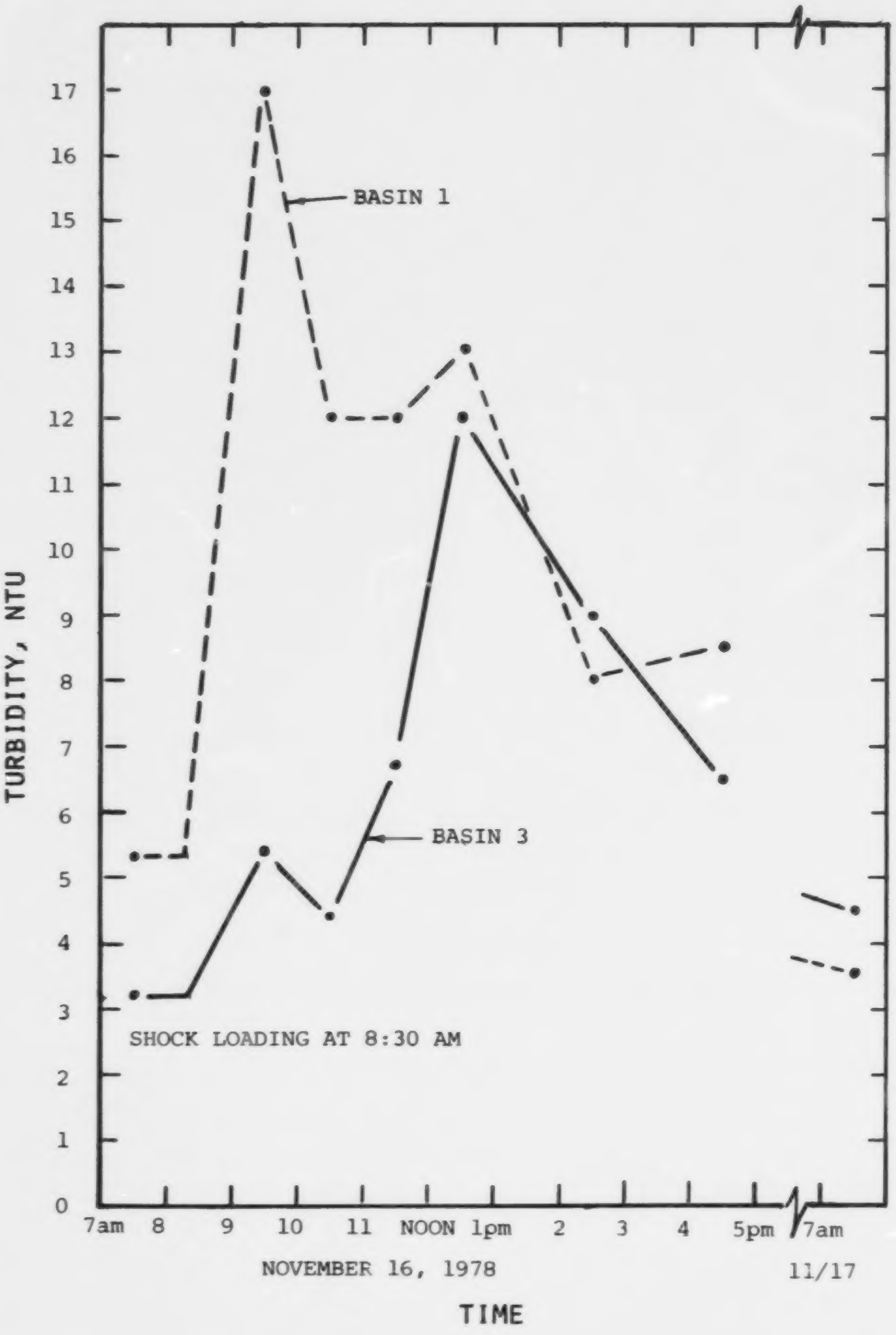

Figure 26. Settlometer supernatant turbidity - Medfield - Phase 3B

SECTION 6

RESULTS AT MARLBOROUGH

PHASE 1 - BASELINE FOR COMPARISON

Operating Parameters

During Phase 1 the plant received an average sewage flow of 0.12 cu m/sec (2.7 mgd). This was slightly more than 50% of the design flow rate. Since only one half of the treatment train was in use, all operating clarifiers and aeration basins were hydraulically loaded at their design capacities.

Phase 1 consisted of a ten-day monitoring period, followed by a single day of inadvertant septage addition, a three-day recovery period and an additional seven days of no-septage monitoring. Process characteristics for Phase 1 are shown in Table 30.

Influent Characteristics

Average values and associated standard deviations for all influent parameters monitored during Phase 1 are shown in Table 31. Influent organic, nitrogen and phosphorus concentrations characterize the wastewater as weak sewage.[17] Total and suspended solids concentrations classify it as a medium strength sewage. Heavy metal concentrations were near or below values recommended for drinking water standards. Measured concentrations were relatively uniform throughout the monitoring period except for the solids data, and standard deviations for these were near or exceeded mean values, indicating large variability.

Primary Clarification

Removals of total BOD and suspended solids by primary clarification averaged 17% and 52%, respectively, during Phase 1. COD and total solids reductions averaged 22% and 33.5%, respectively. These values, shown on Table 32, are lower than would be expected for a system operating at an overflow rate of 29 cu m/sq m-day (712 gal/sq ft-day). The results were due to the weak strength of the sewage.

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[17] Metcalf and Eddy, Inc., Wastewater Engineering, p. 231.

TABLE 30. PROCESS CHARACTERISTICS

MARLBOROUGH - PHASE 1

Characteristic	Mean Value
Flow Rate, Q, cu m/sec (mgd)	0.12 (2.7)
Sludge Return Rate, Stage #1, Qr_1, cu m/sec (mgd)	0.06 (1.4)
Sludge Return Rate, Stage #2, Qr_2, cu m/sec (mgd)	0.22 (5.0)
Qr_1/Q	0.50
Qr_2/Q	1.83
Aeration Basin Retention, Stage #1, hrs	5.11
Aeration Basin Retention, Stage #2, hrs	5.11
Mixed Liquor Suspended Solids, Stage #1, mg/l	1490
Mixed Liquor Vol. Susp. Solids, Stage #1, mg/l	1070
Mixed Liquor Suspended Solids, Stage #2, mg/l	3420
Mixed Liquor Vol. Susp. Solids, Stage #2, mg/l	2170
F/M, kg BOD_5/kg MLVSS/day, Stage #1	0.42
F/M, kg BOD_5/kg MLVSS/day, Stage #2	0.024
F/M, kg TKN/kg MLVSS/day, Stage #2	0.037
Loading, Stage #1, gm BOD_5/cu m-day (lb BOD_5/1000 cu ft-day)	470 (29.3)
Loading, Stage #2, gm BOD_5/cu m-day (lb BOD_5/1000 cu ft-day)	51.3 (3.2)
Loading, Stage #2, gm TKN/cu m-day (lb TKN/1000 cu ft-day)	80.2 (5.0)
Mean Cell Residence, Stage #1, SRT_1, days	2.4
Mean Cell Residence, Stage #2, SRT_2, days	>60
Oxygen Utilization, Stage #1, kg O_2/kg BOD_5	1.15
Oxygen Utilization, Stage #1, kg O_2/kg COD	0.53
Oxygen Utilization, Stage #2, kg O_2/kg BOD_5	18.5
Oxygen Utilization, Stage #2, kg O_2/kg COD	9.7
Oxygen Utilization, Stage #2, kg O_2/kg TKN	10.2

Nitrogen and phosphorus concentrations were unaffected by sedimentation. While there were some reductions in the concentrations of cadmium, chromium and copper, there was a small

TABLE 31. INFLUENT, PRIMARY EFFLUENT, SECONDARY EFFLUENT AND FINAL EFFLUENT MARLBOROUGH - PHASE 1

	Influent		Primary Effluent		Secondary Effluent		Final Effluent	
Characteristics	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
COD - Total, mg/l	317	75	247	134	55	17	39	6.9
COD - Soluble, mg/l	90	24	78	36	37	12	30	8.3
BOD_5 - Total, mg/l	120	40	100	64	11	5.1	2.6	2.1
BOD_5 - N - Suppressed mg/l	87	37	73	48	4.1	3.0	0.8	0.5
Total Solids, mg/l	716	506	476	194	358	108	463	101
Total Volatile Solids mg/l	468	493	193	72	111	68	121	61
Suspended Solids, mg/l	221	376	106	104	10	4.6	6.7	7.9
Vol. Susp. Solids, mg/l	200	366	72	41	7.6	3.8	5.8	6.1
Total Kjeldahl-N, mg/l	20	6.5	27	9.5	17	4.1	1.7	0.9
Ammonia-N, mg/l	16	2.8	17	5.5	13	2.8	0.7	0.9
Nitrate-N, mg/l	1.0	0.3	1.0	0.5	3.2	1.0	17	4.5
Total Phosphorus, mg/l	5.6	2.1	5.5	2.7	1.0	0.5	0.7	0.6
Grease, mg/l	129	11	211	169	52	19	13	11
Alkalinity, mg/l as $CaCO_3$	112	21	136	45	89	31	50	31
pH	6.8	0.3	6.8	0.4	6.8	0.3	6.8	0.4
Dissolved Oxygen, mg/l	3.3	1.0	2.3	2.1	4.4	1.6	5.9	1.7
Temperature	10	1.4	9.4	2.5	10	2.9	10	2.5
Metals, mg/l								
Cadmium	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.01
Chromium	0.04	0.09	0	0	0	0	0	0
Copper	0.20	0.05	0.17	0.07	0.75	1.78	0.09	0.05
Nickel	0.04	0.03	0.06	0.05	0.05	0.04	0.05	0.04
Lead	0.07	0.06	0.27	0.33	0.14	0.06	0.09	0.12
Zinc	0.27	0.09	1.00	1.90	0.72	1.43	0.13	0.06

increase in nickel. Lead and zinc both exhibited substantial increases in average values but standard deviations for these data exceeded the mean values.

TABLE 32. MIXED LIQUOR

MARLBOROUGH - PHASE 1

	Mixed Liquor 1st Stage		Mixed Liquor 2nd Stage First Compartment		Mixed Liquor 2nd Stage Last Compartment	
Characteristic	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Total Solids, mg/l	1,820	489	3,800	353	3,950	412
Total Volatile Solids, mg/l	1,160	365	2,230	197	2,330	254
Suspended Solids, mg/l	1,490	517	3,320	367	3,510	399
Volatile Susp. Solids, mg/l	1,070	379	2,140	182	2,210	255
pH	6.8	0.3	6.9	0.4	6.8	0.3
Temperature, °C	10	1.1	10	0.8	10	0.8
Alkalinity, mg/l as $CaCO_3$	132	34	185	55	184	42
D. O. Uptake, mg/l-hr	20	6.1	46	19	15	4.0
Dissolved Oxygen, mg/l	7.4	1.3	0.7	0.3	8.0	0.9
Total Kjeldahl-N, mg/l	121	33	185	22	163	68
Ammonia-N, mg/l	15	3.9	2.3	1.6	1.7	1.1
Nitrate-N, mg/l	0.9	0.1	12	3.8	15	5.3
Settlometer, 30 minutes ,ml/l	149	35			258	12

Secondary Treatment

Organic loadings on the secondary process (Stage 1) were typical of conventional operations. The F/M ratio was 0.44 and volumetric loading averaged 0.50 kg BOD_5/cu m-day (31 lb BOD_5/1000 cu m ft-day). The ratio was typical of conventional operation, even with the weak sewage, because of the low mixed liquor suspended solids concentration (1,490 mg/l) and the short aeration basin detention time (5.1 hours).

BOD removal in the secondary system averaged 89%. Removal from influent to secondary effluent was 91%. Suspended solids removals, from influent to secondary effluent, averaged 95%, eliciting a secondary effluent concentration of 10 mg/l.

Nitrogen loss or incorporation into cell tissue was very small, amounting to only 1 mg/l. Ninety-five percent of the influent nitrogen was in the secondary effluent. This small usage is not typical and cell incorporation of 5 to 6 mg/l would have been expected for this strength sewage. Nitrification began in the secondary system (Stage 1), raising nitrates from 1 mg/l in the influent to 3.2 mg/l in the secondary effluent.

Aluminum sulfate added to the secondary aeration basins for phosphorus removal, coupled with biological assimilation, reduced phosphorus levels to 1.0 mg/l.

Dissolved oxygen levels remained high throughout Phase 1, averaging 4.4 mg/l. Heavy metals (Cd, Cr, Ni, Pb and Zn) remained at low concentrations. Only copper showed an increase in average value from primary to secondary effluent. Again variability in the copper concentration data was high.

Nitrification Stage

The nitrification stage (Stage 2) further reduced organic concentrations: overall plant BOD_5 removal was 98%. Nitrification was essentially completed with final effluent nitrate nitrogen, TKN and ammonia nitrogen averaging 17, 1.7 and 0.7 mg/l, respectively. From influent to final effluent only 1.6 mg/l of nitrogen were assimilated.

Dissolved oxygen levels during Phase 1 (5.9 mg/l) and mixed liquor volatile suspended solids concentrations (2,170 mg/l) were both conducive to good nitrification system operation. Solids retention time, SRT, for the nitrification system was not calculated because of infrequent sludge wasting, but the SRT was certainly in excess of the recommended 10-20 days.[18] Both temperature (10°C) and pH (6.8) were below values recommended for optimum nitrification but the other parameters (D.O., MLVSS, and SRT) offset the effect of low temperature and pH. The BOD_5/TKN ratio for the influent to the nitrification stage was 0.65, a value which would support a relatively high fraction of nitrifying organisms.

Solids Production

A volatile suspended solids, VSS, balance for Phase 1 is shown in Table 33. Items included in the balance are influent VSS, VSS removed with the vacuum filter cake, changes in mixed liquor volatile suspended solids inventory for each of the aeration stages and the production of VSS by conversion of waste organics to cells. Production was the computed difference between inputs and outputs. A balance of VSS was preferred to a total suspended solids balance because of the large amounts of ferric chloride and lime used in waste sludge conditioning.

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[18] Ibid., p. 667.

TABLE 33. VOLATILE SUSPENDED SOLIDS BALANCE

MARLBOROUGH - PHASE 1

	Volatile	Suspended Solids
Sample	Input	Output
Influent, kg/day	953	
(lb/day)	(2,102)	
Effluent, kg/day		23
(lb/day)		(50)
Change in MLVSS, kg/day		(211)
Stage #1, (lb/day)		465
Change in MLVSS, kg/day	12	
Stage #2, (lb/day)	(27)	
Cake, kg/day		1,404
(lb/day)		(3,096)
Biological Sludge Production, kg/day	672	
(lb/day)	(1,482)	
Totals, Kg/day	1,637	1,638
(lb/day)	(3,611)	(3,611)

The sludge yield factor, based upon computed sludge production values, was 0.29 kg of VSS produced per kg of BOD_5 removed. This value is lower than the expected value, Y_{obs}, given by the equation:

$$Y_{obs} = \frac{Y}{1 + k_d\theta_c}$$

where the mean cell residence time, θ_c, was 2.4 days in the secondary system and published values for the endogenous decay rate, k_d, and yield without decay, Y, are 0.055 $days^{-1}$ and 0.5 kg VSS produced per kg BOD_5 removed. The equation given an expected Y_{obs} of 0.44. The difference in expected and recorded yield factors is most likely due to a change in the solids inventory carried in the clarifiers between wasting periods.

Heavy metals were concentrated in the filter cake with concentrations on a dry solids basis, ranging from 0.01% for cadmium to 0.73% for zinc.

Vacuum filter filtrate at Marlborough was a strong waste stream with obnoxious characteristics. It has high COD, BOD, TKN, and ammonia concentrations as well as a high pH. Metal concentrations were low, probably as a result of hydroxide precipitation. The odor of this is as unpleasant as that of septage. (See Tables 34 and 35.) Ferric chloride and lime usage averaged 152 kg/day (334 lb/day) and 2,950 kg/day (6,486 lb/day), respectively.

PHASE 2 - CONTINUOUS FEEDING

Process Characteristics

Operating parameters for the constant feed studies, Phases 2A and 2B, are shown on Table 36. Influent flow averaged 0.103 cu m/sec (2.3 mgd) during Phase 2A and 0.12 cu m/sec (2.75 mgd) during Phase 2B. These flows were close to the average Phase 1 flow rate, 0.12 cu m/sec (2.7 mgd). In each of the Phase 2 studies mixed liquor solids concentrations and clarifier and aeration basin retention times were similar to Phase 1 values. Processes were operated at near hydraulic design capacities.

Septage loading averaged 110 cu m/day (29,000 gals/day) in Phase 2A. The test lasted three days with a septage volume equal to 1.25% of the average daily sewage flow rate. The organic material added by septage was mostly removed in primary clarification. As a result, organic loading, mean cell residence time and oxygen utilization in the secondary and nitrification stages were almost identical to baseline values (Compare Tables 30 and 36). Increased loading due to septage organics passing the primary clarifier was offset by a 15% reduction in sewage flow.

In Phase 2B 375 cu m (99,000 gals) of septage were added over a period of 42 hours. The septage volume was 2.14% of the average daily sewage flow rate. Process characteristics shown on Table 36 indicate that septage did not increase secondary and nitrification process loading during this period.

Influent Characteristics

Sewage characteristics for Phase 2 are shown in Tables 37 and 38 and can be compared with baseline values in Table 31.

TABLE 34. RETURN SLUDGE AND COMBINED SLUDGE

MARLBOROUGH - PHASE 1

Characteristics	Returned Sludge 1st Stage x̄	s	Returned Sludge 2nd Stage x̄	s	Combined Sludge x̄	s
COD-Total, mg/l						
COD-Soluble, mg/l						
BOD-Total, mg/l						
BOD-N Suppressed						
Total Solids, mg/l, %	3,640	1,650	5,920	931	47,100	13,200
Total Volatile Solids, mg/l, %	2,550	1,420	3,520	548	30,100	8,700
Suspended Solids, mg/l	3,180	1,660	5,450	925	44,200	12,500
Volatile Susp. Solids mg/l	2,390	1,420	3,420	547	28,000	8,250
pH						
Total Kjeldahl-N, mg/l	284	179	324	105	1,540	657
Ammonia-N, mg/l	16	6.2	3.6	3.2	225	157
Nitrate-N, mg/l	1.7	3.1	12	5.8	6.4	3.4
Total Phosphorus, mg/l					1,010	338
Capillary Suction Time, sec	14	8.2	8.3	1.2	359	103
Metals, mg/kg dry cake						
Cadmium					0.45	0.18
Chromium					7.50	3.85
Copper					29.90	14.21
Nickel					3.47	1.43
Lead					9.97	3.56
Zinc					26.38	13.43

Sewage was weak during the test with small increases observed during the Phase 2B period. In this second constant feed test COD increased 12%, BOD 41%, suspended solids 23% and TKN 270% over baseline values. Total solids decreased 21%.

Characteristics of septage used in Phase 2 and calculated concentrations of the combined sewage and septage influent are also shown on Tables 37 and 38. The septage was quite strong. It effectively doubled the organic and phosphorus loading on the

TABLE 35. VACUUM FILTER FILTRATE AND CAKE

MARLBOROUGH - PHASE 1

Characteristics	Vacuum Filtrate		Vacuum Filter Cake	
	$\bar{x}$	s	$\bar{x}$	s
COD-Total, mg/l	5,080	960		
COD-Soluble, mg/l	4,170	1,110		
BOD-Total, mg/l	3,250	1,050		
BOD-N Suppressed	2,720	1,210		
Total Solids, mg/l, %	7,880	1,710	25.6	3.3
Total Volatile Solids, mg/l, %	2,230	697	9.3	1.6
Suspended Solids, mg/l	927	193		
Volatile Susp. Solids, mg/l	227	41		
pH	12.1	0.1		
Total Kjeldahl-N, mg/l	662	933		
Ammonia-N, mg/l	381	143		
Nitrate-N, mg/l	14	5.7		
Total Phosphorus, mg/l	25	18		
Metals, mg/l, mg/kg dry cake				
Cadmium	0.06	0.02	121	19
Chromium	0.04	0.10	1,231	443
Copper	0.40	0.05	4,142	771
Nickel	0.37	0.08	735	100
Lead	0.47	0.07	1,726	336
Zinc	0.87	1.00	7,339	1,470

plant in Phase 2A. Solids and nitrogen loading increased by about 30%. Septage nearly tripled the COD loading in Phase 2B and doubled the solids and phosphorus loads.

Primary Effluent

A comparison of Tables 37 and 39 shows the effects of primary clarification on the combined sewage-septage influent for

TABLE 36. PROCESS CHARACTERISTICS

MARLBOROUGH - PHASE 2

Phase	2A	2B
Flow Rate, Z, cu m/sec (mgd)	0.103 (2.3)	0.12 (2.75)
Septage Feed Rate, cu m/day (gpd)	110 (29,000)	216 (57,000)
Septage/Sewage, %	1.25	2.14
Sludge Return, Stage #1, cu m/sec (mgd)	0.067 (1.5)	0.07 (1.6)
Sludge Return, Stage #2, cu m/sec (mgd)	0.245 (5.6)	0.28 (6.4)
Aeration Retention, Stage #1, hrs	5.91	4.91
Aeration Retention, Stage #2, hrs	5.91	4.91
MLSS , Stage #1, mg/l	1,197	1,480
MLVSS, Stage #1, mg/l	947	1,150
MLSS , Stage #2, mg/l	3,409	3,417
MLVSS, Stage #2, mg/l	2,147	2,180
F/M, kg BOD_5/kg MLVSS-day, Stage #1	0.45	0.54
F/M, kg BOD_5/kg MLVSS-day, Stage #2	0.017	0.017
F/M, kg TKN/kg MLVSS-day, Stage #2	0.034	0.034
Loading, Stage #1, gm BOD_5/cu m-day (lb BOD_5/1000 cu ft-day)	423 (26.4)	625 (39.0)
Loading, Stage #2, gm BOD_5/cu m-day (lb BOD_5/1000 cu ft-day)	35.8 (2.23)	36.9 (2.3)
Loading, Stage #2, gm TKN/cu m-day (lb TKN/1000 cu ft-day)	74.1 (4.62)	73.8 (4.6)
Mean Cell Residence, Stage #1, days	2.5	3.69
Mean Cell Residence, Stage #2, days	>60	>60
Oxygen Use, Stage #1, kg O_2/kg BOD_5	1.11	0.69
Oxygen Use, Stage #1, kg O_2/kg COD	0.42	0.40
Oxygen Use, Stage #2, kg O_2/kg BOD_5	31.7	17.31
Oxygen Use, Stage #2, kg O_2/kg COD	13.2	13.20
Oxygen Use, Stage #2, kg O_2/kg TKN	14.1	8.45

Phase 2A. Solids added with septage increased both suspended and total solids concentrations in the primary effluent. Pri-

TABLE 37. SEWAGE, SEPTAGE AND COMBINED INFLUENT MARLBOROUGH - PHASE 2A

Characteristic	Sewage $\bar{x}$	Sewage s	Septage $\bar{x}$	Septage s	Combined Sewage and Septage*
COD-Total, mg/l	305	62	24,500		602
COD-Soluble, mg/l	96	25			
BOD_5-Total, mg/l	129	8.1	7,410		218
BOD_5-N Suppressed, mg/l	112	15	5,900		183
Total Solids, mg/l	707	245	16,970		907
Total Volatile Solids, mg/l	537	310	12,420		683
Suspended Solids, mg/l	280	118	14,530		455
Vol. Susp. Solids, mg/l	234	117	10,780		363
Total Kjeldahl-N, mg/l	26	0.7	730		35
Ammonia-N, mg/l	20	1.4	170		22
Nitrate-N, mg/l	1.3	0.3			
Total Phosphorus, mg/l	5.5	1.2	480		11
Grease, mg/l	171	66	1,643		189
pH	6.9	0	6.4		6.9
Temperature, ^{o}C	12	0			
Alkalinity mg/l as $CaCO_3$	132	2.3	830		142
Metals, mg/l					
Cadmium	0.01	0.01	0.02	0.02	0.01
Chromium	0	0	2.0	0.74	0.02
Copper	0.19	0.04	18.3	4.1	0.41
Nickel	0	0	0.78	0.14	0.01
Lead	0.05	0.07	2.9	0.76	0.08
Zinc	0.29	0.01	4.9	1.8	0.35

*Calculated concentrations

mary effluent suspended solids averaged 199 mg/l during Phase 2A and only 106 mg/l in Phase 1. COD values were much higher during the period but total BOD_5 did not change. Septage caused an increase of about 22% in TKN levels and 64% in ammonia. Phosphorus levels in primary effluent were unaffected by septage addition.

TABLE 38. SEWAGE, SEPTAGE AND COMBINED INFLUENT

MARLBOROUGH - PHASE 2B

Characteristic	Sewage		Septage	Combined Sewage and Septage *
	x	s	$\bar{x}$	$\bar{x}$
COD-Total, mg/l	354	115	27,500	905
COD-Soluble, mg/l	73	14		
BOD_5-Total, mg/l	169	44	11,180	393
BOD_5-N Suppressed, mg/l	120	7.8	8,450	289
Total Solids, mg/l	564		18,940	937
Total Volatile Solids, mg/l	308		14,450	595
Suspended Solids, mg/l	272		15,270	577
Volatile Susp. Solids, mg/l	246		12,160	488
Total Kjeldahl-N, mg/l	54	16	640	66
Ammonia-N, mg/l	13	2.1	100	15
Nitrate-N, mg/l	0.9	0.3		
Total Phosphorus, mg/l	5.3	2.8	220	9.7
Grease, mg/l	209		3,121	268
pH	6.7	0.1	4.6	6.7
Temperature, °C	12	0		
Alkalinity, mg/l as $CaCO_3$	117	7.8	0	115
Metals, mg/l				
Cadmium	0		0.08	0
Chromium	0		1.0	0.02
Copper	0.20		13.4	0.48
Nickel	0		0.16	0
Lead	0.18		2.0	0.22
Zinc	0.28		15.0	0.59

*Calculated concentrations

The primary clarifier removed 49% of the combined influent COD, 53% of the BOD_5 and 56% of the suspended solids, in Phase 2A. This compares with Phase 1 COD, BOD_5 and suspended solids removals of 22%, 17% and 52%, respectively.

TABLE 39. PRIMARY EFFLUENT, SECONDARY EFFLUENT AND FINAL EFFLUENT

MARLBOROUGH - PHASE 2A

Characteristic	Primary Effluent		Secondary Effluent		Final Effluent	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
COD-Total, mg/l	310	16	62	24	45	4.3
COD-Soluble, mg/l	98	26	52	18	38	2.3
BOD_5-Total, mg/l	103	13	8.7	6.9	1.6	0.7
BOD_5-N Suppressed, mg/l	69	4.8	2.6	0.6	1.1	0.1
Total Solids, mg/l	592	57	395	54	479	23
Total Volatile Solids, mg/l	298	91	158	23	237	12
Suspended Solids, mg/l	199	25	18	4.4	18	12
Volatile Susp. Solids, mg/l	137	15	9	6	15	10
Total Kjeldahl-N, mg/l	33	0.9	18	0.5	2.0	0.3
Ammonia-N, mg/l	28	7.0	17	2.1	0.5	0.2
Nitrate-N, mg/l	0.9	0.1	4.4	0.5	20	0.6
Total Phosphorus, mg/l	5.4	5.4	0.8	0.1	1.4	0.8
Grease, mg/l	135	35	35.2		6.2	0.9
pH	7.2	0.1	7.1	0.2	6.9	0.2
Temperature, °C	12	0	13	0	13	0
Dissolved Oxygen, mg/l	2.0	1.9	2.1	1.4	5.5	0.5
Alkalinity, mg/l as $CaCO_3$	192	2.0	106	30	46	7.8
Metals, mg/l						
Cadmium	0	0	0.02	0.02	0.02	0.02
Chromium	0	0	0	0	0	0
Copper	0.20	0.06	0.06	0	0.17	0.13
Nickel	0.05	0.07	0.05	0.03	0	0
Lead	0.09	0.12	0.08	0.11	0.06	0.08
Zinc	0.56	0.05	0.12	0.01	0.68	0.30

At the 2.14% loading, Phase 2B, primary effluent was only slightly stronger than concentrations measured during Phase 1. Primary effluent concentrations are shown in Table 40. Table 41 shows a comparison of Phase 2B and Phase 1 influent and

TABLE 40. PRIMARY EFFLUENT, SECONDARY EFFLUENT AND FINAL EFFLUENT

MARLBOROUGH - PHASE 2B

Characteristic	Primary Effluent		Secondary Effluent		Final Effluent	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
COD-Total, mg/l	255	64	46	4.5	38	2.4
COD-Soluble, mg/l	80	15	33	15	34	10
BOD_5-Total, mg/l	128	28	7.8	3.4	1.7	0.5
BOD_5-N Suppressed, mg/l	76	20	1.9	0.4	0.6	0.5
Total Solids, mg/l	477	60	364	22	489	14
Total Volatile Solids, mg/l	206	92	82	57	164	62
Suspended Solids, mg/l	143	31	10	0.6	13	4.0
Volatile Susp. Solids, mg/l	101	38	7.3	1.2	8.0	2.6
Ammonia-N, mg/l	20	5.8	13	6.0	1.0	1.0
Nitrate-N, mg/l	0.8	0.1	2.7	0.7	18	2.5
Total Phosphorus, mg/l	6.1	0.5	0.9	0.6	1.0	0.4
Grease, mg/l	914		51.2		24.8	
pH	6.9	0.2	6.7	0.2	6.5	0.1
Dissolved Oxygen, mg/l	1.4	0.9	3.0	1.2	5.7	0.7
Temperature, °C	13	1.0	14	0.6	13	0.7
Alkalinity, mg/l as $CaCO_3$	156	6.7	98	18	38	2.9
Metals, mg/l						
Cadmium	0		0.03		0	
Chromium	0		0.50		0	
Copper	0.16		0.09		0.07	
Nickel	0.10		0.11		0.10	
Lead	0.14		0.07		0	
Zinc	8.6		0.21		0.32	

TABLE 41. RATIOS OF CHARACTERISTICS
MARLBOROUGH - PHASES 2A & 2B

Characteristics	Influent Phase 2A / Phase 1	Influent Phase 2B / Phase 1	Primary Phase 2A / Phase 1	Effluent Phase 2B / Phase 1
COD-Total, mg/l	1.90	2.85	1.26	1.03
COD-Soluble, mg/l			1.26	1.11
BOD_5-Total, mg/l	1.82	3.28	1.03	1.28
BOD_5-N Suppressed, mg/l	2.10	3.32	0.95	1.04
Total Solids, mg/l	1.27	1.31	1.24	1.00
Total Vol. Solids, mg/l	1.46	1.27	1.54	1.07
Suspended Solids, mg/l	2.06	2.61	1.88	1.35
Vol. Susp. Solids, mg/l	1.82	2.44	1.90	1.40
Total Kjeldahl-N, mg/l	1.75	3.30	1.22	1.22
Ammonia-N, mg/l	1.38	0.94	0.90	1.18
Total Phosphorus, mg/l	1.96	1.73	0.98	1.11
Alkalinity, mg/l as $CaCO_3$	1.27	1.03	1.41	1.15

primary effluent characteristics. The ratios listed on Table 41 clearly show that a three-fold increase in combined influent COD, BOD_5 and suspended solids yielded almost no increase in primary effluent COD and about a 30% increase in BOD_5 and suspended solids.

Efficiency of removal in Phase 1 and in Phase 2B is contrasted in Table 42. Low percent removals shown for Phase 1 were due to the weak strength of the sewage. The high percentages shown for Phase 2B on Table 42 indicate that a large fraction of the organic material in septage is associated with suspended solids which are readily settled in primary clarification.

Secondary Treatment

A comparison of Tables 31 and 39 shows that a septage/sewage feed ratio of 1.25%, Phase 2A, caused no noticeable deterioration in secondary effluent quality. Secondary effluent suspended solids increased but remained well within regulatory standards, averaging 18 mg/l. In contrast, the total BOD_5

TABLE 42. EFFICIENCY OF PRIMARY CLARIFIERS
MARLBOROUGH - PHASES 2A & 2B

	Percent Removal		
Characteristics	Phase 1	Phase 2A	Phase 2B
COD-Total, mg/l	22	49	72
COD-Soluble, mg/l	13		
BOD_5-Total, mg/l	17	53	67
BOD_5-N Suppressed, mg/l	16	62	74
Total Solids, mg/l	34	35	49
Total Vol. Solids, mg/l	59	56	65
Suspended Solids, mg/l	52	56	75
Vol. Susp. Solids, mg/l	64	62	79
Total Kjeldahl-N, mg/l	-35	6	50
Ammonia-N, mg/l	- 6	-27	-33
Total Phosphorus, mg/l	2	51	37

dropped about 20% to 8.7 mg/l. Efficiencies of BOD_5 and suspended solids removal in the secondary treatment units alone averaged 92% and 91%, respectively, during Phase 2A.

The aerator settings remained the same during Phases 1 and 2A but average secondary effluent dissolved oxygen levels dropped from 4.4 to 2.1 mg/l. This was unexpected since the F/M ratios were the same (0.45 for Phase 2A and 0.42 for Phase 1) as were dissolved oxygen uptake rates (18 mg/l-hr for Phase 2A and 20 mg/l-hr for Phase 1). The difference in dissolved oxygen concentration was probably caused by surges in influent flow, transferring high D.O. water from the aeration basin to the secondary clarifier. Oxygen measurements were not taken at exactly the same time each morning.

Mixed liquor volatile suspended solids were 12% lower during Phase 2A, averaging 947 mg/l. This value is low when compared with conventional activated sludge practice, but effluent quality remained excellent. Mixed liquor data are shown in Table 43.

In Phase 2B, primary effluent BOD loading and the F/M ratio were higher than in Phase 1 and 2A. The F/M ratio (0.54 kg BOD_5/kg MLVSS-day) was about 25% higher than that used for conventional activated sludge processes. Mean cell residence time increased from 2.4 and 2.5 days during Phases 1 and

TABLE 43. MIXED LIQUOR

MARLBOROUGH - PHASE 2A

Characteristics	Mixed Liquor 1st Stage		Mixed Liquor 2nd Stage First Compartment		Mixed Liquor 2nd Stage Last Compartment	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Total Solids, mg/l	1,630	234	3,837	221	3,853	792
Total Volatile Solids, mg/l	1,110	223	2,327	129	2,337	512
Suspended Solids, mg/l	1,197	196	3,450	425	3,367	773
Volatile Susp. Solids, mg/l	947	181	2,130	175	2,163	480
pH	6.9	0.1	6.7	0.1	6.7	0.1
Temperature, °C	13	0	13	0	13	0
Alkalinity, mg/l as $CaCO_3$	154	15	180	11	167	6.1
D. O. Uptake, mg/l-hr	18	2.1	66	6.0	11	2.1
Dissolved Oxygen, mg/l	6.5	1.0	0.6	0.3	7.8	0.8
Total Kjeldahl-N, mg/l	131	22	198	37	223	22
Ammonia-N, mg/l	17	4.0	2.2	1.7	0.8	0.6
Nitrate-N, mg/l	1.1	0.4	14	2.5	17	1.7
Settlometer, 30 min,ml/l	123	2.9			223	5.8

2A, respectively, to 3.7 days in Phase 2B. Average characteristics of the secondary effluent are shown in Table 40. In every case, contaminant levels were equal to or less than those of Phase 1, despite the addition of septage at a septage/sewage ratio of 2.14% BOD and suspended solids removal efficiencies in the secondary treatments alone averaged 94% and 93%, respectively.

There was a drop in the effluent dissolved oxygen from 4.4 mg/l in Phase 1 to 3.0 mg/l in Phase 2B. This change can be attributed to the change in temperature from 10°C in Phase 1 to 14°C in Phase 2B.

The mixed liquor volatile suspended solids concentration was about the same in Phases 1 and 2B and settleability remained good (SVI averaged 127 ml/gram). The increase in the F/M ratio in Phase 2B did not raise the oxygen utilization rate; in fact, there was a slight decrease from Phase 1 of about 15%. These data are shown in Table 44.

TABLE 44. MIXED LIQUOR

MARLBOROUGH - PHASE 2B

Characteristics	Mixed Liquor 1st Stage $\bar{x}$	s	Mixed Liquor 2nd Stage First Compartment $\bar{x}$	s	Mixed Liquor 2nd Stage Last Compartment $\bar{x}$	s
Total Solids, mg/l	1,870	389	3,337	1,947	4,307	284
Total Volatile Solids, mg/l	1,270	303	1,960	1,182	2,557	112
Suspended Solids, mg/l	1,480	272	2,933	1,896	3,900	252
Volatile Susp. Solids mg/l	1,150	221	1,887	1,157	2,473	55
pH	6.9	0.2	6.6	0.1	6.6	0.2
Temperature, °C	13	0.6	13	0.6	13	0.6
Alkalinity, mg/l as $CaCO_3$	140	14.8	134	11	156	13
D. O. Uptake, mg/l-hr	17	2.7	32	29	11	1.4
Dissolved Oxygen, mg/l	6.1	1.2	0.5	0.2	8.2	0.1
Total Kjeldahl-N, mg/l	177	32	247	56	293	104
Ammonia-N, mg/l	14	5.6	5.1	5.1	1.0	0.3
Nitrate-N, mg/l	0.9	0.2	13	4.2	15	4.4
Settlometer, 30 minutes,ml/l	188	42			213	5.8

Nitrification Stage

Performance of the nitrification stage in Phase 2 was almost identical to that of Phase 1. The only exception was a slight increase in suspended solids and in the fraction of total volatile solids. Nitrification was almost complete with the effluent averaging 18 to 20 mg/l nitrate-N and containing only 2.0 mg/l TKN and 0.5 to 1.0 mg/l ammonia-N.

Final effluent quality was not affected by the addition of the septage, with the possible exception of the grease content, which was significantly higher in Phase 2 than during background monitoring. It should be recognized that this conclusion is based on only one grease analysis during Phase 2B.

Biological Solids Production

Throughout Phases 1, 2A and 2B no intentional sludge wastage occurred from the nitrification section of the plant. Primary sludge and excess first stage activated sludge were routinely wasted. Because of the short duration of Phases 2A and 2B, meaningful solids balances could not be made.

Since organic loadings on secondary and nitrification stages were not increased by addition of septage up to 2.14%, no increase in excess activated sludge was expected. Increases in primary effluent concentrations shown in Table 41 were caused by corresponding increases in influent sewage levels. The increased solids handled by the plant were derived from suspended solids added to the primary clarifier by septage. For Phase 2A this increase amounted to 1,597 kg/day (3,514 lb/day) and for Phase 2B, 3,300 kg/day (7,260 lb/day). Using the data for SRT and MLSS in Stage #1, septage increased wasted solids by 54% during Phase 2A and 100% during Phase 2B.

Characteristics of the return sludge, combined sludge, vacuum filter filtrate and cake were similar during septage addition phases. Data are shown in Tables 45, 46 and 47.

Conditioning of sludge was accomplished using ferric chloride and lime. Operating records indicated an average ferric chloride dosage of about 3% on a dry solids basis. This was a typical value. In contrast, lime dosage averaged 60% based on dry solids. This usage is six to eight times normal values.

PHASE 3 - SHOCK LOADING

The first shock loading test at Marlborough, Phase 3A, lasted three days. At 7 a.m. each morning 79.5 cu m (21,000 gals) of septage was added to the primary clarifier within a period of thirty minutes. Sewage flow during this test averaged 9,590 cu m/day (2.53 mgd). The septage/sewage flow ratio was 0.83% on a total daily quantity basis. The instantaneous septage/sewage ratio for the thirty-minute period of septage addition was about 30%.

The second shock loading test, Phase 3B, lasted two days. At 7 a.m. each morning 148 cu m (39,000 gals) of septage were released from storage: 79.5 cu m (21,000 gals) during the first thirty minutes and the remainder over the next one and one-half hours. In addition, 45.4 cu m (12,000 gals) were added at 2 p.m. on the second day. The septage/sewage ratio was 1.8% on the first day and 2.3% on the second day.

TABLE 45. RETURN SLUDGE AND COMBINED SLUDGE
MARLBOROUGH - PHASE 2A

Characteristics	Return Sludge 1st Stage		Return Sludge 2nd Stage		Combined Sludge	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Total Solids, mg/l	2,700	373	6,710	364	63,780	4,270
Total Vol. Solids, mg/l	1,860	335	4,120	151	35,510	2,770
Susp. Solids, mg/l	2,260	361	6,210	341	58,960	4,920
Vol. Susp. Solids, mg/l	1,640	351	3,920	181	42,360	2,840
Total Kjeldahl-N, mg/l	206	34	335	9.9	1,820	317
Ammonia-N, mg/l	18	1.0	1.5	1.0	152	109
Nitrate-N, mg/l	1.2	0.3	13	3.2	12	1.7
Total Phosphorus, mg/l					1,870	601
CST, sec.	11	1.4	8.0	0.9	309	154
Metals, mg/l						
Cadmium	0.78	0.25	0.07	0.01	150	18.4
Chromium	12.6	4.8	0	0	1,057	344
Copper	46.2	3.1	0.38	0.01	4,529	354
Nickel	5.0	1.1	0.29	0.02	631	166
Lead	13.5	2.3	0.46	0.06	1,817	51.6
Zinc	15.3	0.64	0.51	0.14	9,463	5,008

TABLE 46. RETURN SLUDGE AND COMBINED SLUDGE
MARLBOROUGH - PHASE 2B

Characteristics	Return Sludge 1st Stage		Return Sludge 2nd Stage		Combined Sludge	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Total Solids, mg/l	3,220	546	5,990	754	68,090	7,040
Total Vol. Solids, mg/l	2,240	353	3,667	601	36,720	1,820
Susp. Solids, mg/l	2,520	62	5,520	709	62,670	5,630
Vol. Susp. Solids, mg/l	2,130	312	3,547	575	33,720	1,460
Total Kjeldahl-N, mg/l	261	78	412	40	1,980	40
Ammonia-N, mg/l	12	2	2.3	0.9	300	40
Nitrate-N, mg/l	0.9	0.2	11	5.8	13	2.6
Total Phosphorus, mg/l					1,230	475
CST, sec.	18	9.4	8.7	0.4	327	97
Metals, mg/l						
Cadmium					0.60	0.05
Chromium					11.2	0
Copper					42.8	0.38
Nickel					2.40	0.28
Lead					9.60	0.35
Zinc					13.3	1.61

TABLE 47. VACUUM FILTER FILTRATE AND CAKE
MARLBOROUGH - PHASE 2A & 2B

	2A - Vacuum Filter			2B - Vacuum Filter		
	Filtrate		Cake	Filtrate		Cake
Characteristics	$\bar{x}$	s	$\bar{x}$	$\bar{x}$	s	$\bar{x}$
COD-Total, mg/l	4,880	149				
COD-Soluble, mg/l	4,000	79				
BOD_5-Total, mg/l	2,897	443				
BOD_5-N Sup., mg/l	2,590	265				
Tot. Solids,mg/l,(%)	8,000	478	(25.1)	8,090	269	(26.6)
Tot. Vol. Solids, mg/l (%)	2,390	340	(8.8)	2,030	711	(9.3)
Susp. Solids, mg/l	893	436		1,030	259	
Vol. Susp. Solids, mg/l	267	97		350	26	
pH	12	0		11.9	0.1	
Total Kjeldahl-N, mg/l	420	16		383	0	
Ammonia-N, mg/l	410	42		347	50	
Nitrate-N, mg/l	93	25		13	3.5	
Tot. Phosphorus, mg/l	12	3.3		15	8.4	
Metals,mg/l, mg/kg dry cake						
Cadmium	0.07	0.01	150	0.05		189
Chromium	0	0	1,057	0		1,891
Copper	0.38	0.01	4,529	0.38		4,312
Nickel	0.29	0.02	631	0.28		605
Lead	0.46	0.06	1,817	0.35		2,043
Zinc	0.51	0.14	9,463	1.61		6,052

Sewage and Septage Characteristics

Phase 3 sewage was characteristic of a weak to moderate strength domestic waste and similar to influent monitored during the baseline period. Average values for both shock load periods are shown on Table 48. These values can be compared with baseline characteristics on Table 31.

Average septage characteristics for the period are also shown on Table 48. Septage used for the two tests was comparatively strong with COD and total solids averaging 28,500 mg/l and 17,400 mg/l, respectively. Daily septage and sewage characteristics values for Phase 3 are given in Appendix Tables I-1 and I-2.

Primary Effluent

An effect of large septage inputs to a primary clarifier is apparent in Figures 27 through 30. In all cases organic and solids concentrations in the primary effluent increased

TABLE 48. SEWAGE AND SEPTAGE CHARACTERISTICS
MARLBOROUGH - PHASE 3

Characteristics	Sewage $\bar{x}$	Sewage s	Septage $\bar{x}$
COD-Total, mg/l	334	50	28,500
COD-Soluble, mg/l	99	43	
BOD-Total, mg/l	116	28	7,950
BOD-N Sup., mg/l	64	21	6,660
Total Solids, mg/l	503	76	17,400
Tot. Vol. Solids, mg/l	269	101	12,700
Susp. Solids, mg/l	209	158	15,200
Vol. Susp. Solids, mg/l	188	150	11,400
Total Kjeldahl-N, mg/l	35	15	637
Ammonia-N, mg/l	19	2.6	213
Nitrate-N, mg/l	1.2	0.5	
Alkalinity, mg/l as $CaCO_3$	126	11	900
pH	6.7	0.1	5.4

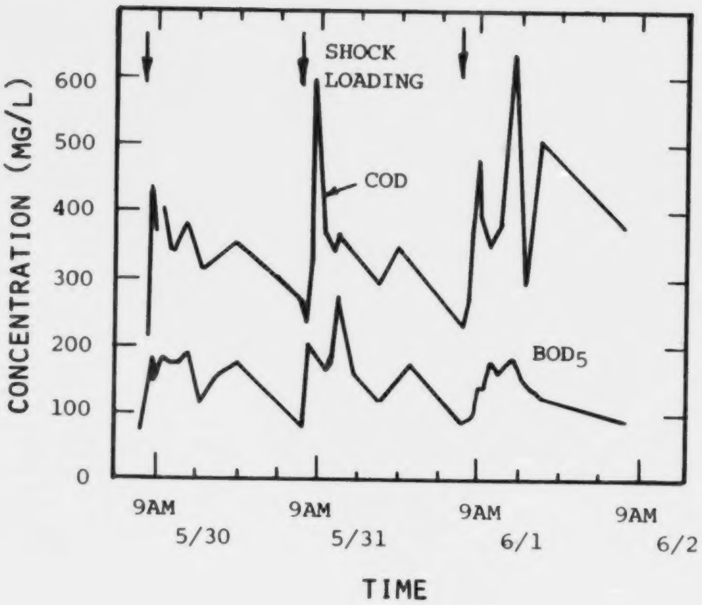

Figure 27. Primary effluent COD and BOD_5 - Marlborough - Phase 3A.

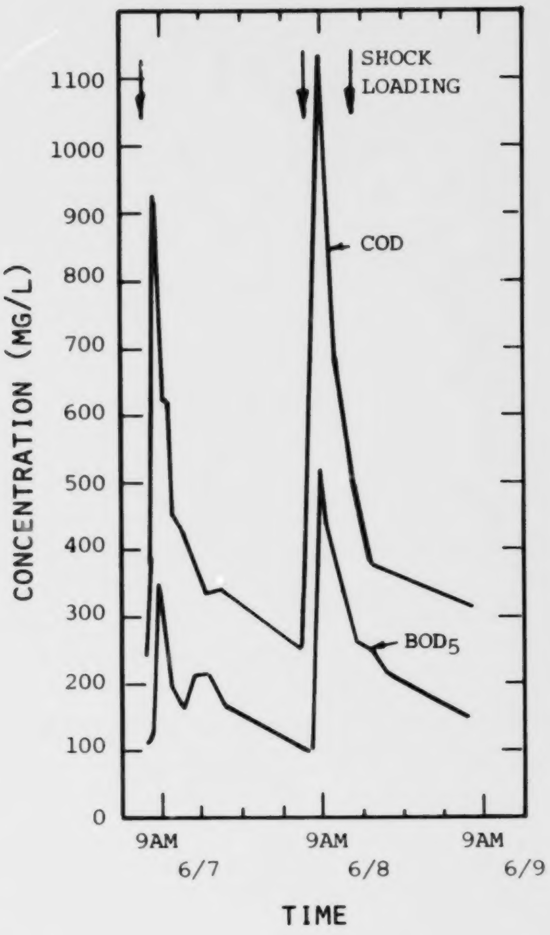

Figure 28. Primary effluent COD and BOD_5 - Marlborough - Phase 3B.

very shortly after beginning the feeding operation. Figures 27 and 28 show that COD and BOD_5 values increased significantly within one hour of beginning the test, reached a maximum value within one and one-half and two hours, and declined to background levels within four to six hours. Total and suspended solids data on Figures 29 and 30 show the same result. Peak values were reached in about one-third the clarifier design retention time. Septage addition was directly related to peak concentrations. Peak COD and BOD_5 values during Phase 3B were about twice as high as during Phase 3A. While the short time

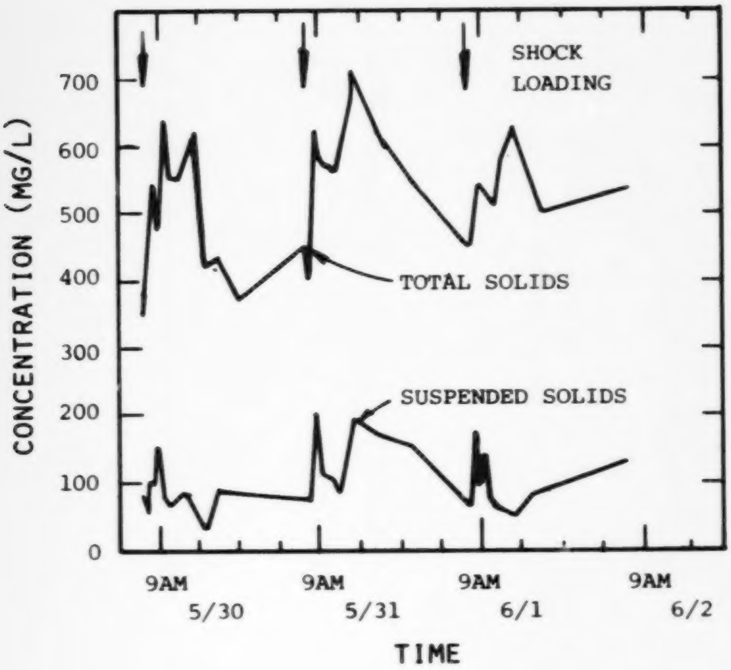

Figure 29. Primary effluent total and suspended solids - Marlborough - Phase 3A.

increase in organic and solids concentrations observed during Phase 3 were dramatic, the impact on 24-hour composited samples was not significant.

Dilution and clarification in the primary clarifier were analyzed by considering the shock load a step input and by comparing the effluent peak values with the theoretical concentration of the step input. If material were conserved and moved in plug flow, the ratio of input concentration to peak concentration would be 1.0. Calculation of the step input concentration was done by mass balance over the one-half hour loading period. Septage-sewage chemical characteristics obviously are not conservative in the liquid fraction, but ratios would be much higher if the mixture followed a plug flow mode. For example, a typical suspended solids influent to effluent ratio for sewage is 0.2 to 0.4. For the sewage-septage mixture this ratio would probably be somewhat lower because of the heavy nature of some septage suspended solids, but not as low as the calculated value, 0.1, unless significant short circuiting and/or intermixing existed.

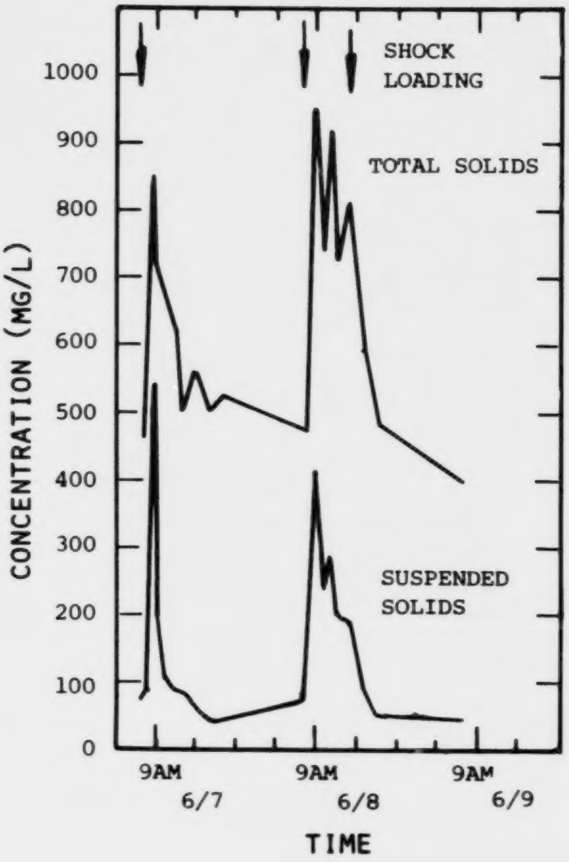

Figure 30. Primary effluent total and suspended solids - Marlborough - Phase 3B.

Primary Clarification

During Phase 3B samples were taken from the primary clarifier before shock loading and periodically after loading. Samples were taken from a point one-half the distance from inlet to effluent weir and at depths of 0.3, 1.5, and 3.0 meters. In addition, samples were taken at the same times from the effluent weir. All samples were analyzed for total solids.

Septage was introduced during Phase 3B at the rate of 2.65 cu m/min (700 gpm) for the first 38 minutes and then at 0.56 cu m/min (150 gpm) for the following 82 minutes.

Figure 31 shows total solids concentrations found as a function of depth of the various sampling times. It can be

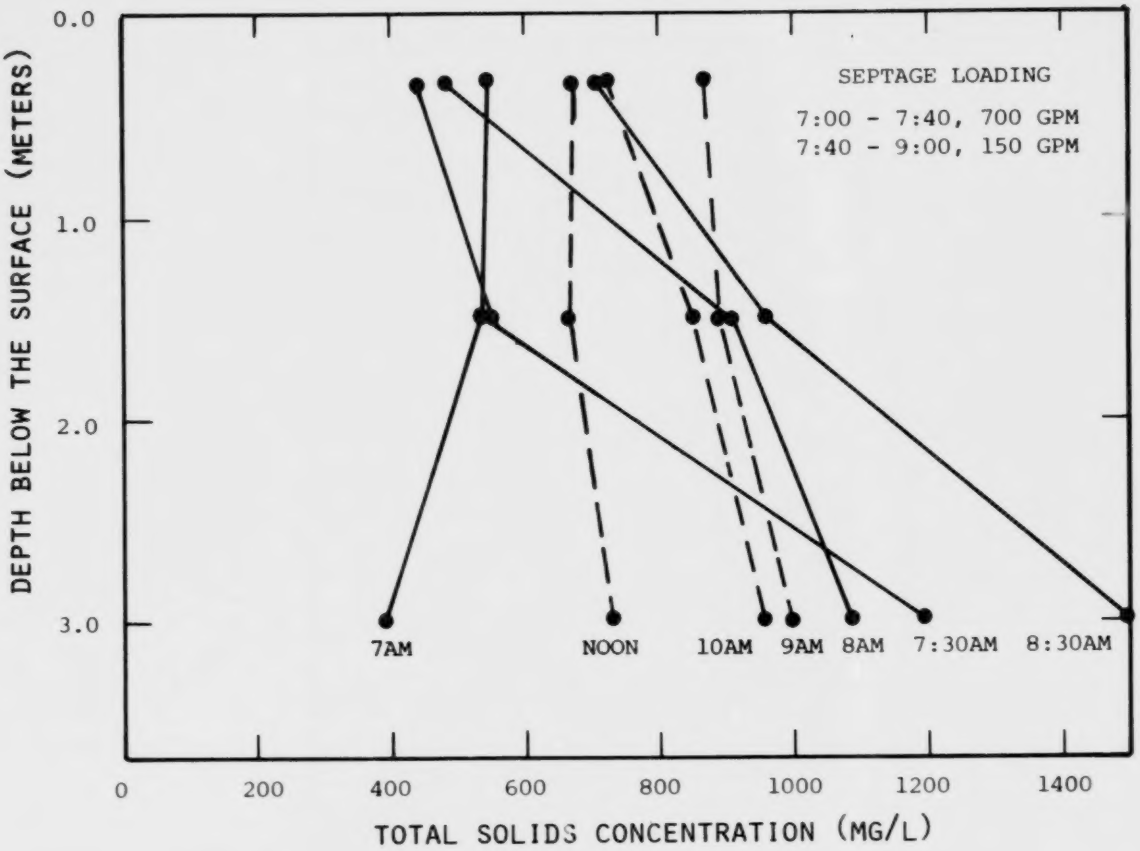

Figure 31. Primary clarifier total solids profiles - Marlborough - Phase 3.

seen that the concentration levels increased with depth throughout the loading period (between 7 a.m. and 9 a.m.). Peak values occurred near the end of the loading period. After 8:30 a.m. concentrations steadily declined and were comparatively more uniform with depth.

In Figure 32 concentration values are plotted against time. Effluent concentrations reach a maximum at the same time as those taken at the intermediate depth. This indicates that a significant amount of mixing and short circuiting occurred. The time to reach maximum values was about two-thirds of the theoretical detention time.

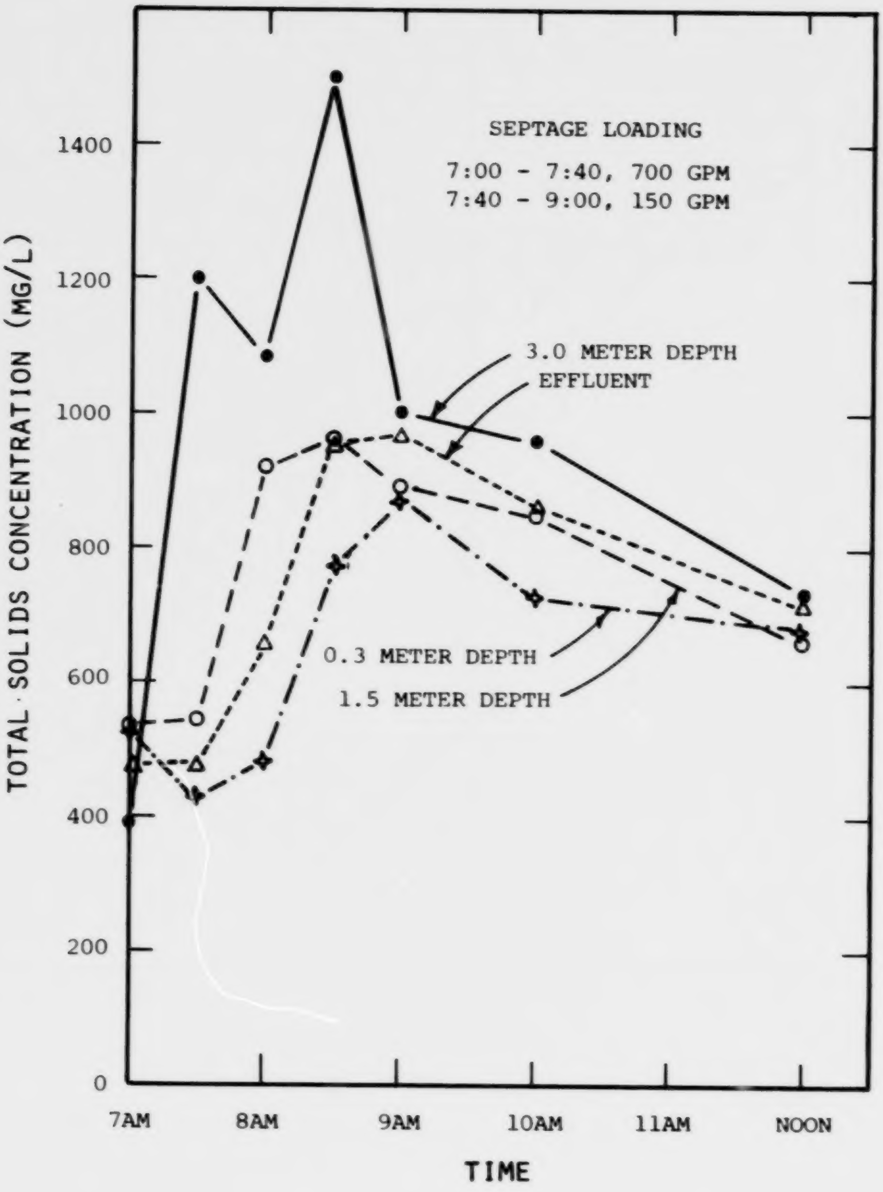

Figure 32. Primary clarifier total solids distribution - Marlborough - Phase 3.

Further substantiation of this non-ideal behavior is shown in Figures 33 and 34. Figure 33 shows two effects of impulse loading on a sedimentation tank: ideal plug flow and displacement with dispersion. Figure 34 shows a similar dimensionless

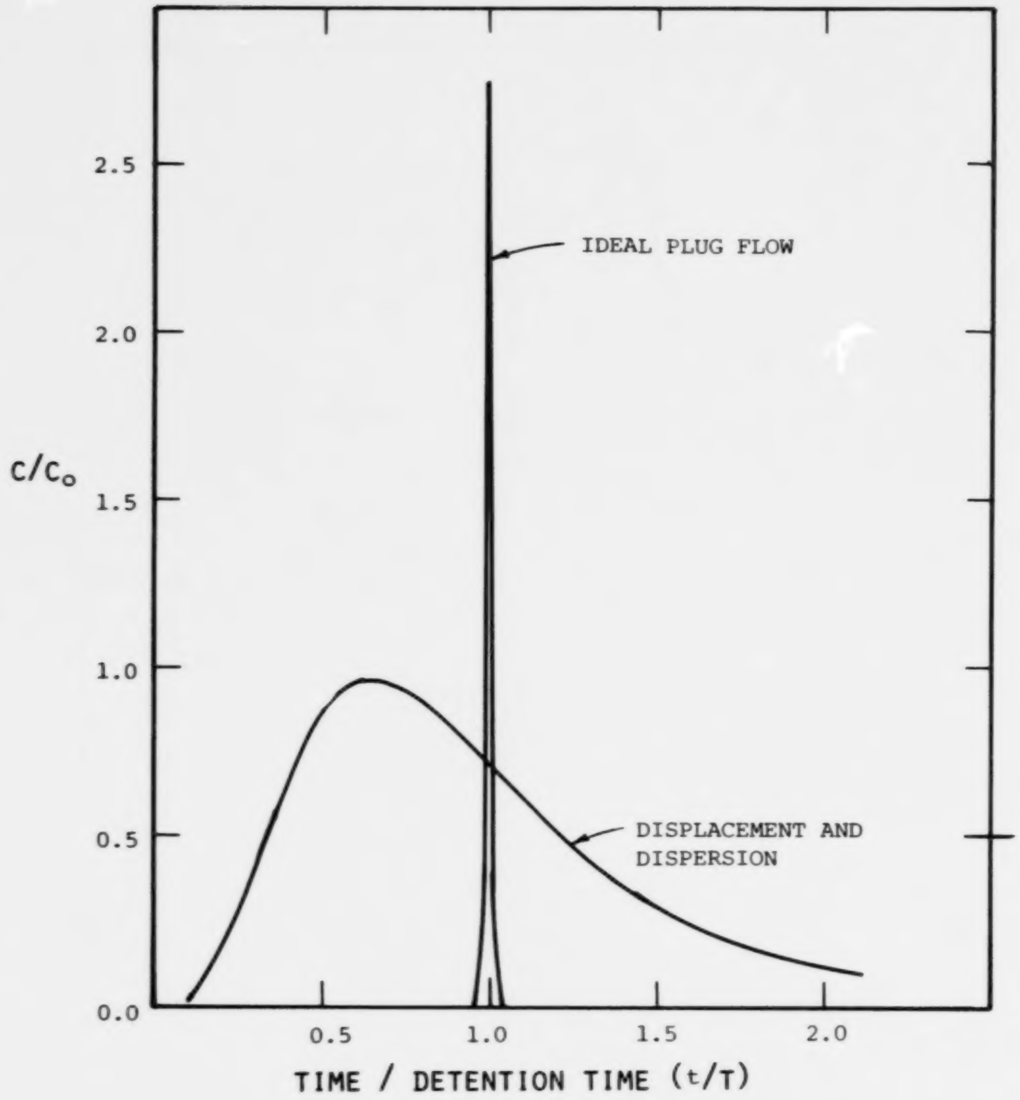

Figure 33. Clarifier effluent responses to a pulse input.

plot of Phase 3B data. While the septage loading was not truly an impulse input, the resulting effluent curve (Figure 34) is similar to that of a system exhibiting a large amount of dispersion.

The data suggest that as septage enters the clarifier, a portion of the solids rapidly falls to lower levels, causes

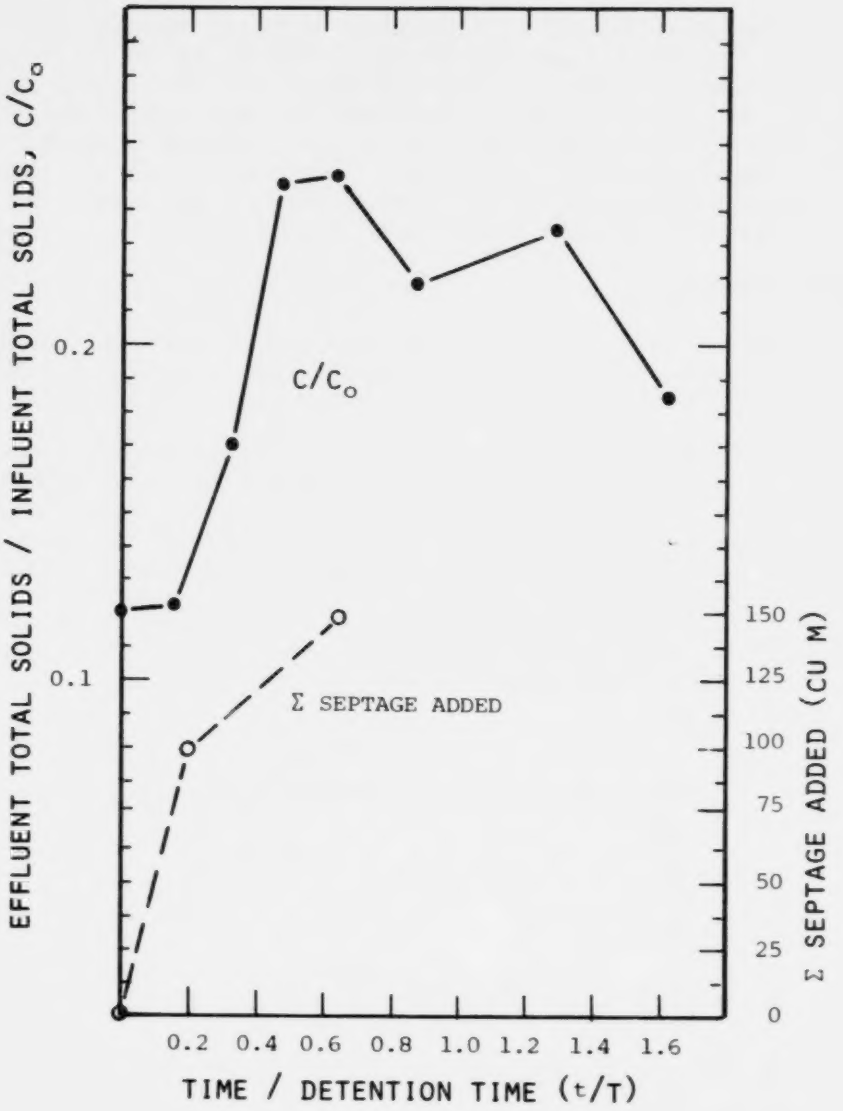

Figure 34. Primary clarifier, effluent total solids/influent total solids - Marlborough - Phase 3.

turbulence and creates density currents which mix the septage with the tank contents. This effect produces the rapid rise in effluent solids concentration.

Although short circuiting occurred, the primary clarifier performed very well from the standpoint of suspended solids removal. Considering an eleven-hour period, beginning with the shock load, the clarifier received 3,890 kg (8,550 lbs) of influent suspended solids and passed only 727 kg (1,600 lbs) over the weir. The removal efficiency was 81 percent. The high removal efficiency is a result of a significant removal of heavy particles associated with septage. At the end of this eleven-hour period, suspended solids levels in the effluent had fallen to values similar to pre-shock conditions.

Secondary Treatment

The impact of septage on the secondary process at Marlborough is shown on Figures 35 through 46. Detailed results are presented in the Appendix Table I-4.

Effluent COD levels in Phase 3 were generally higher than observed during Phase 1, but septage seems to have had little impact on this observation, since pre-shock and post-shock levels were also high. Figures 35 and 36 show that in three days COD increased significantly after septage addition. The elevated COD may have represented refractory organics associated with septage but may also have been caused by morning sewage flow surges. In any event, COD increases were of small magnitude and not accompanied by corresponding increases in BOD_5.

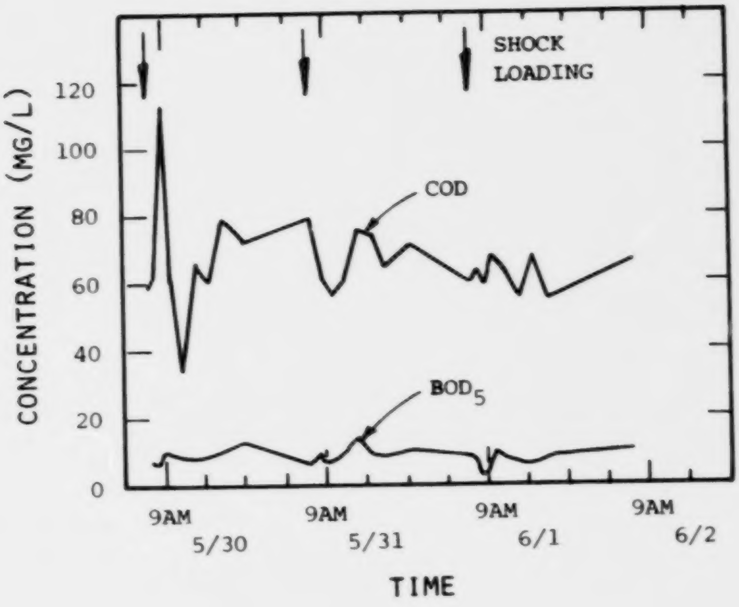

Figure 35. Secondary effluent COD and BOD_5 - Marlborough - Phase 3A.

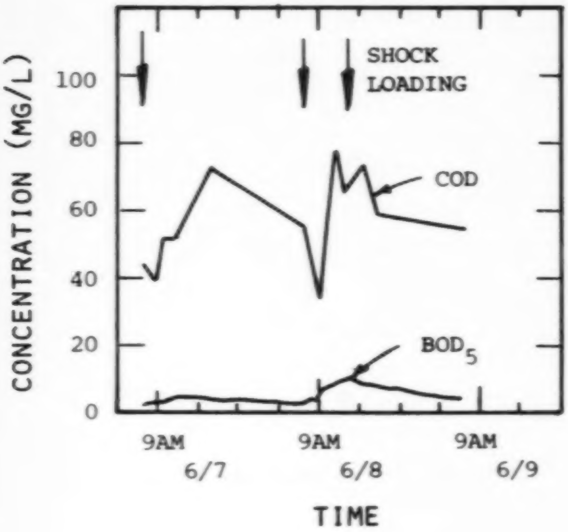

Figure 36. Secondary effluent COD and BOD_5 - Marlborough - Phase 3B.

The influence of the septage was most evident in the effluent solids data shown on Figures 37 and 38.

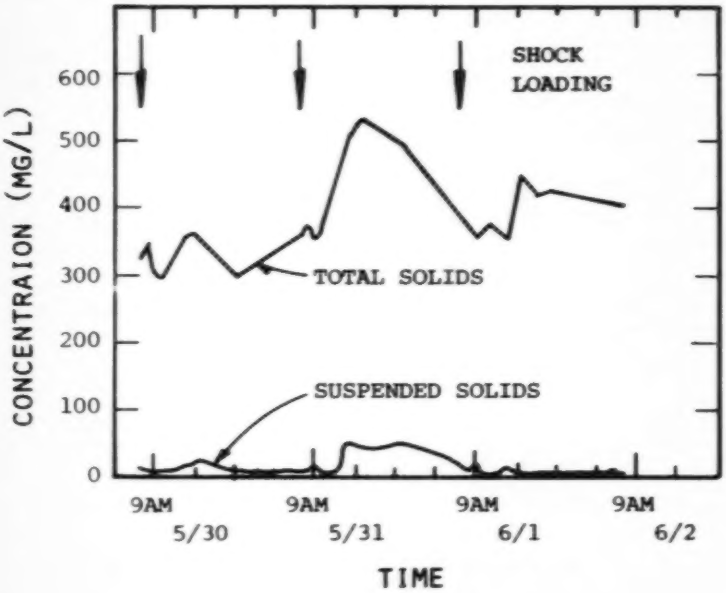

Figure 37. Secondary effluent total and suspended solids - Marlborough - Phase 3A.

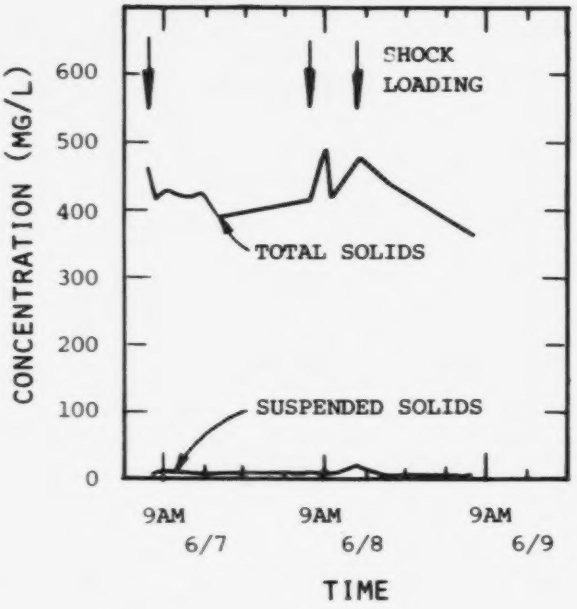

Figure 38. Secondary effluent total and suspended solids - Marlborough - Phase 3B.

There was a definite increasing trend in the effluent total solids concentrations during both test periods. Late in the afternoon of the second day of both tests, solids concentrations reached maximum values. Primary effluent maximum concentrations of total and suspended solids occurred two to three hours prior to the peak secondary effluent concentrations.

Nitrogen data for Phase 3 are plotted on Figures 39 and 40. Septage appears to have increased effluent TKN and ammonia levels in both tests. But influent sewage concentrations were higher than baseline values during Phase 3. Secondary effluent nitrate nitrogen decreased about 1 mg/l. The rapid increase in ammonia concentration shown on Figures 39 and 40 was caused by both septage and surges of sewage flow.

Shock loading had a pronounced effect on mixed liquor dissolved oxygen (Figures 41 and 42). Within five hours of imposing a shock, dissolved oxygen had fallen to a minimum for the day. Mixed liquor temperatures were higher in Phase 3 than in Phase 1 (17^oC versus 10^oC) and as a result dissolved oxygen levels were lower, even with the increased aerator output in Phase 3. Increased mixed liquor solids added to the dissolved oxygen demand in Phase 3B.

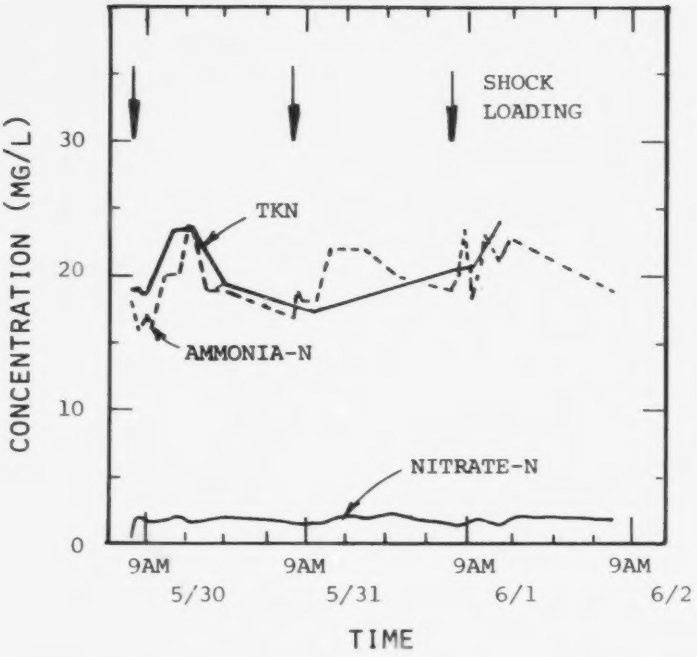

Figure 39. Secondary effluent nitrogen - Marlborough - Phase 3A.

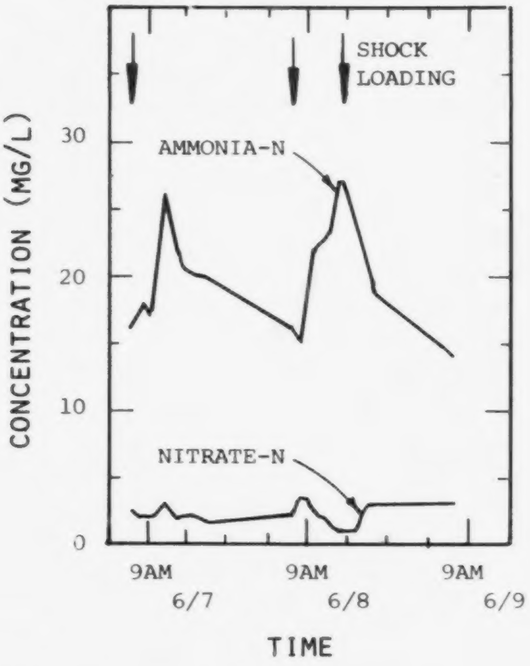

Figure 40. Secondary effluent nitrogen - Marlborough - Phase 3B.

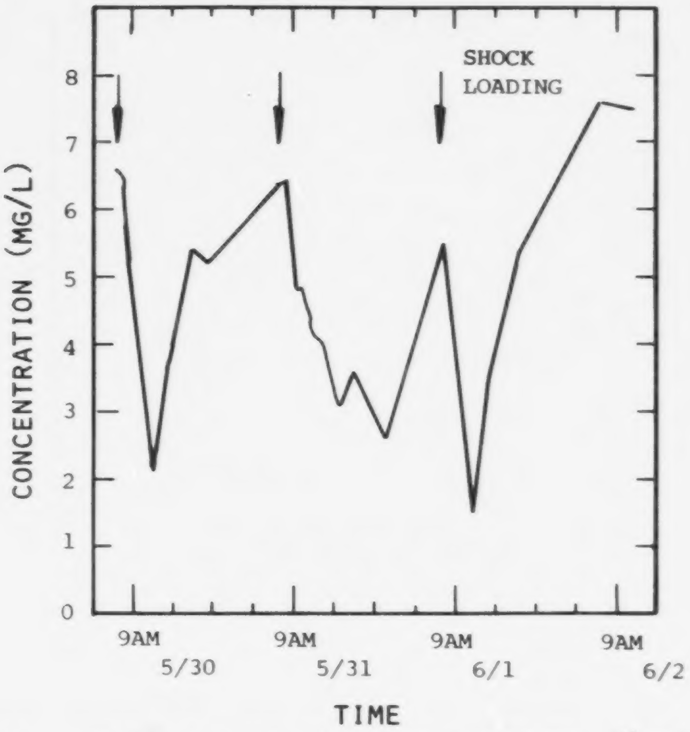

Figure 41. Mixed liquor dissolved oxygen, first stage - Marlborough - Phase 3A.

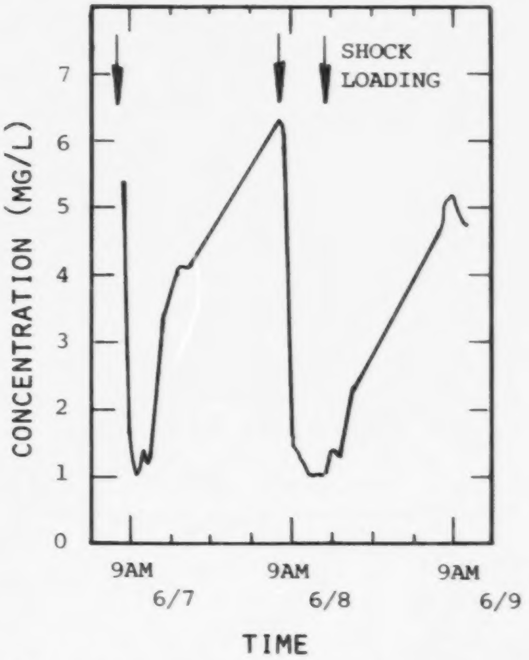

Figure 42. Mixed liquor dissolved oxygen, first stage - Marlborough - Phase 3B.

Dissolved oxygen uptake data, shown on Figures 43 and 44, also show the impact of septage. Peak values occurred three to five hours after septage addition. Average dissolved oxygen uptake rates were similar in Phases 3A and 1 but Phase 3B average values were higher than all preceding tests. This was not caused by septage but rather by comparatively high mixed liquor solids concentration.

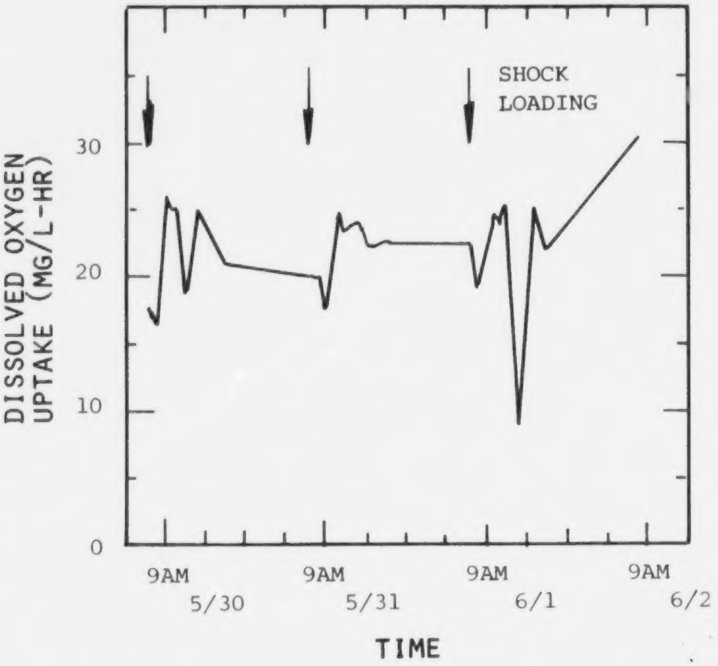

Figure 43. Mixed liquor dissolved oxygen uptake, first stage - Marlborough - Phase 3A.

A striking rise in settlometer data was observed in Phase 3A. Thirty-minute values are shown on Figure 45. Over the three days, settlometer readings increased 50%, from 120 ml/liter to 180 ml/liter, in a linear manner. Shortly after septage additions (within two hours) settlometer readings had fallen slightly, 10 ml/liter to 20 ml/liter, and then increased throughout the day. For each day after the shock period began, the highest settlometer readings were obtained just before initiating that day's shock load. This was caused by long nighttime periods of low feed and extended aeration time. SVI varied from a low of 75 to a high of 110 ml/g - an excellent settling range. The increase in settlometer readings over the three-day period was caused by an increase in mixed liquor suspended solids from 1,070 mg/l to 1,540 mg/l. The percent

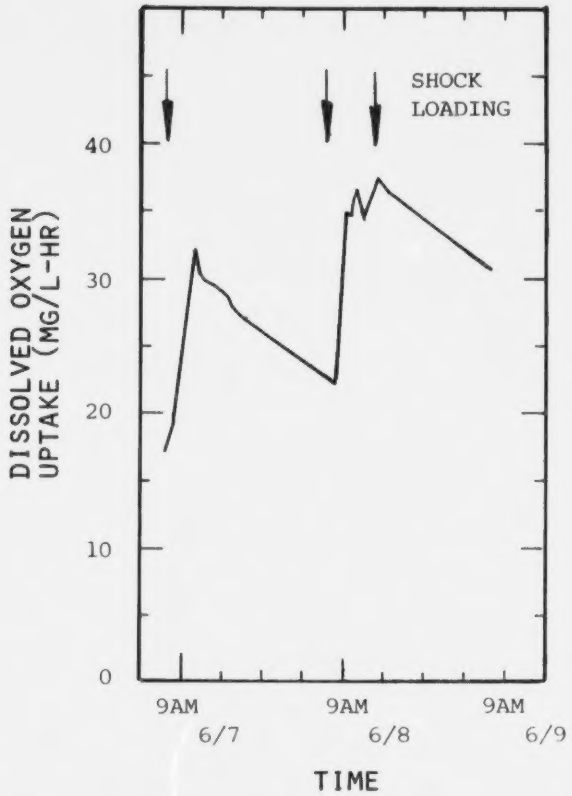

Figure 44. Mixed liquor dissolved oxygen uptake, first stage - Marlborough - Phase 3B.

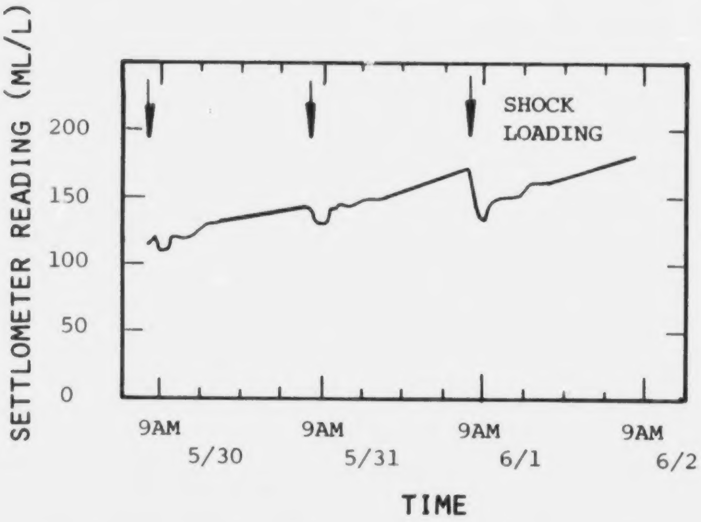

Figure 45. Thirty-minute settlometer, first stage - Marlborough-Phase 3A.

of volatiles of the mixed liquor suspended solids remained almost invariant at 73% over the entire period.

A similar increase in thirty-minute settlometer readings was observed in Phase 3B. The increase, 40 ml, was small but the trend was real. The average value, 158 ml per gram, was essentially the same as in Phase 1 (Figure 46).

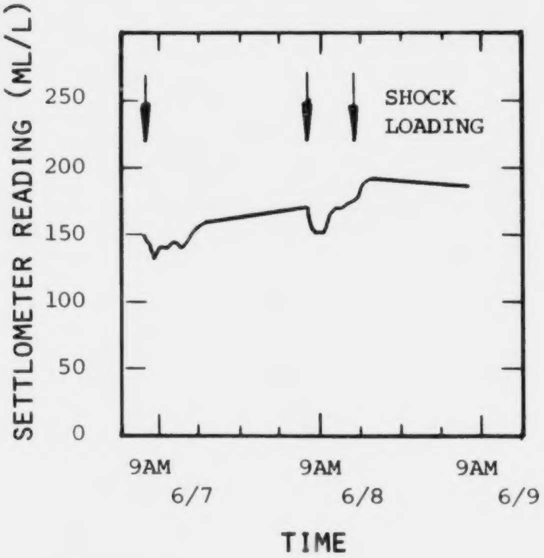

Figure 46. Thirty-minute settlometer, first stage - Marlborough - Phase 3B.

Nitrification Stage (Stage 2)

Excellent tertiary treatment was achieved in Phase 3. Final effluent COD, BOD_5 and suspended solids concentrations were about the same as those of the baseline period. Values are plotted on Figures 47 through 50. Effluent total volatile solids were 30% higher in Phase 3A than in Phase 1, but returned to Phase 1 levels in Phase 3B. Peak total solids concentrations occurred at the same time as those in secondary effluent, three to five hours after primary effluent concentrations were at maximum. This indicates that the concentration perturbations monitored were caused by hydraulic surges in sewage flow and not by septage input.

Nitrate nitrogen concentrations in final effluent were four to five mg/l higher in Phase 3 (17 mg/l Phase 1; 20.7 mg/l Phase 3A; 21.7 mg/l Phase 3B). The rise in nitrates reflected similar

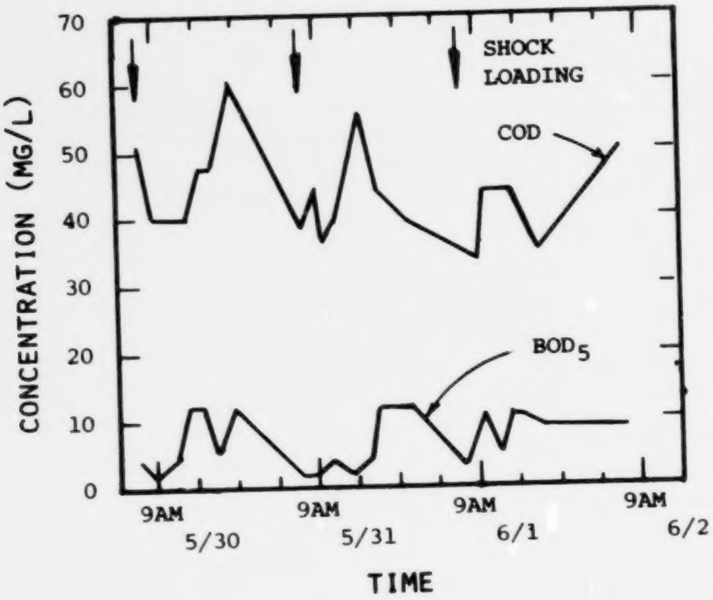

Figure 47. Final effluent COD and BOD_5 - Marlborough - Phase 3A.

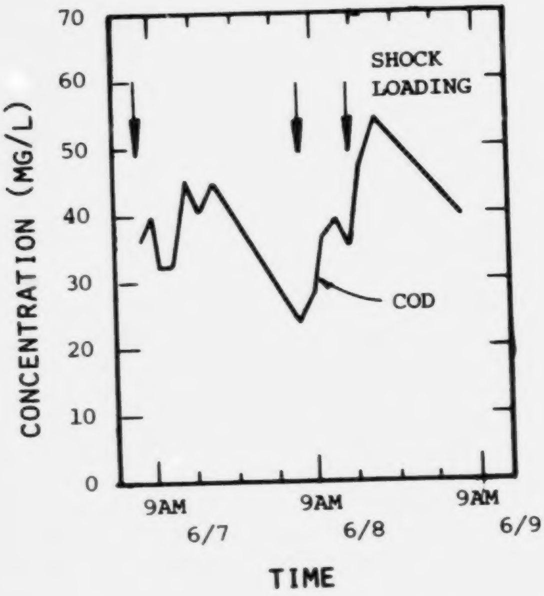

Figure 48. Final effluent COD - Marlborough - Phase 3B.

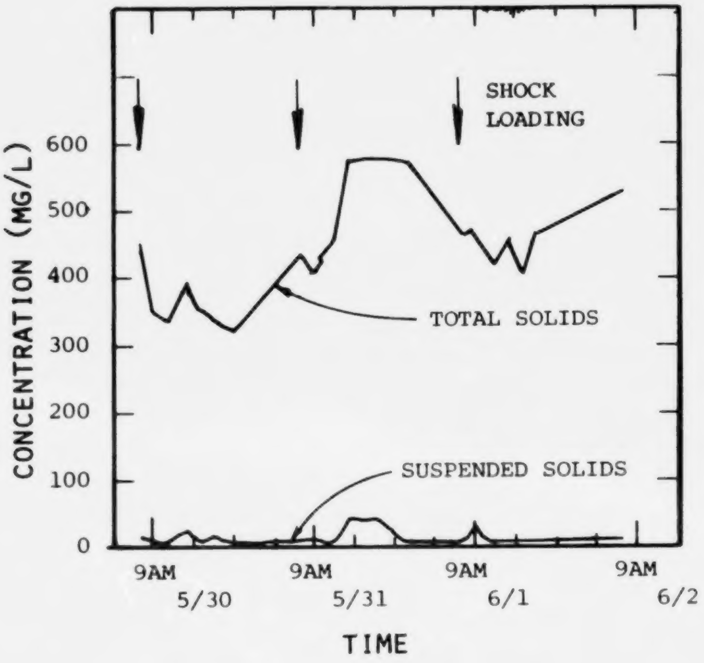

Figure 49. Final effluent total and suspended solids - Marlborough - Phase 3A.

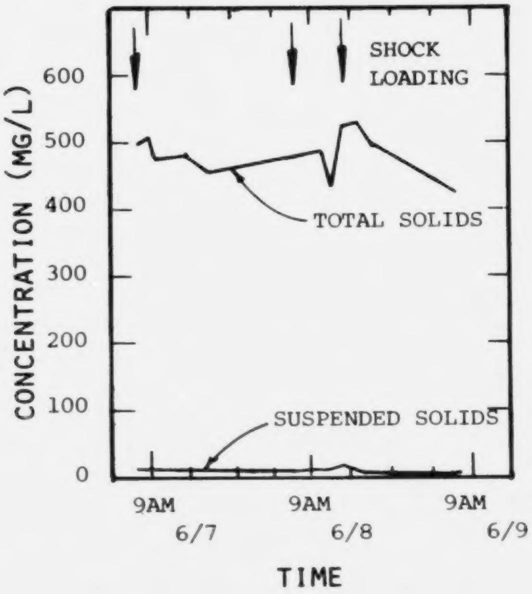

Figure 50. Final effluent total and suspended solids - Marlborough - Phase 3B.

increases in secondary effluent TKN values. Increased nitrification was a result of the additional food provided to nitrifying organisms by septage and an increased sewage ammonia source. Ammonia nitrogen and TKN averaged 0.63 mg/l (S = 0.41) and 2.5 mg/l (S = 0.49) respectively in Phase 3 (Refer to Appendix Table I-5).

Most of the nitrification at Marlborough was accomplished in the first compartment of the plant's nitrification section. This is substantiated by mixed liquor nitrate values, dissolved oxygen levels, and the dissolved oxygen uptake rates (See Figures 51 through 54). Settlometer readings were relatively constant throughout Phase 3 (Figures 55 and 56). For the loading applied in Phase 3 the nitrification stage was not measurably influenced by septage addition.

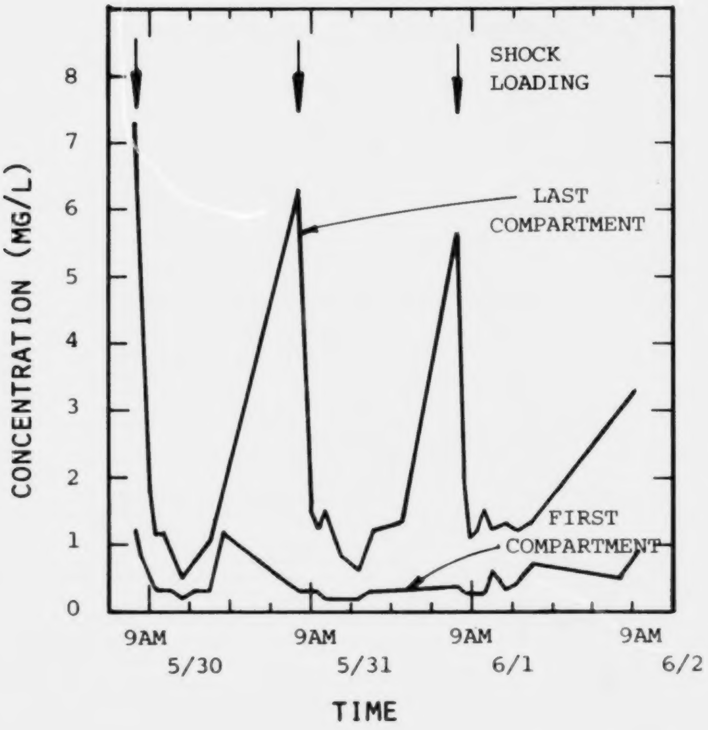

Figure 51. Dissolved oxygen, first and last compartment, second stage - Marlborough - Phase 3A.

Dissolved oxygen uptake rates in the first compartment showed significant variations between early morning and later in the day. For example, the 7:00 a.m. values averaged 14.6 mg/l-hr, while samples collected between 8:00 a.m. and 6:00 p.m.

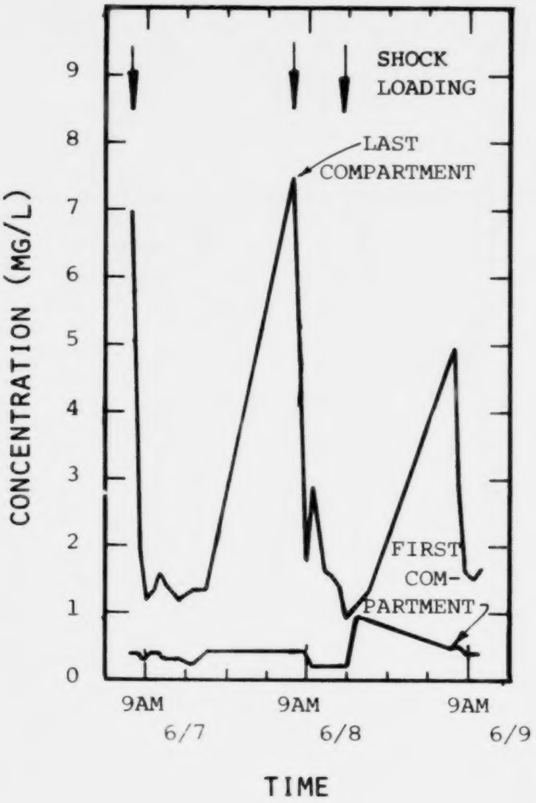

Figure 52. Dissolved oxygen, first and last compartment, second stage - Marlborough - Phase 3B.

averaged 83 mg/l-hr. Septage did not affect the culture, but rather the normal increase in daily flow displaced large quantities of secondary clarifier liquid between 7:00 and 8:00 a.m.

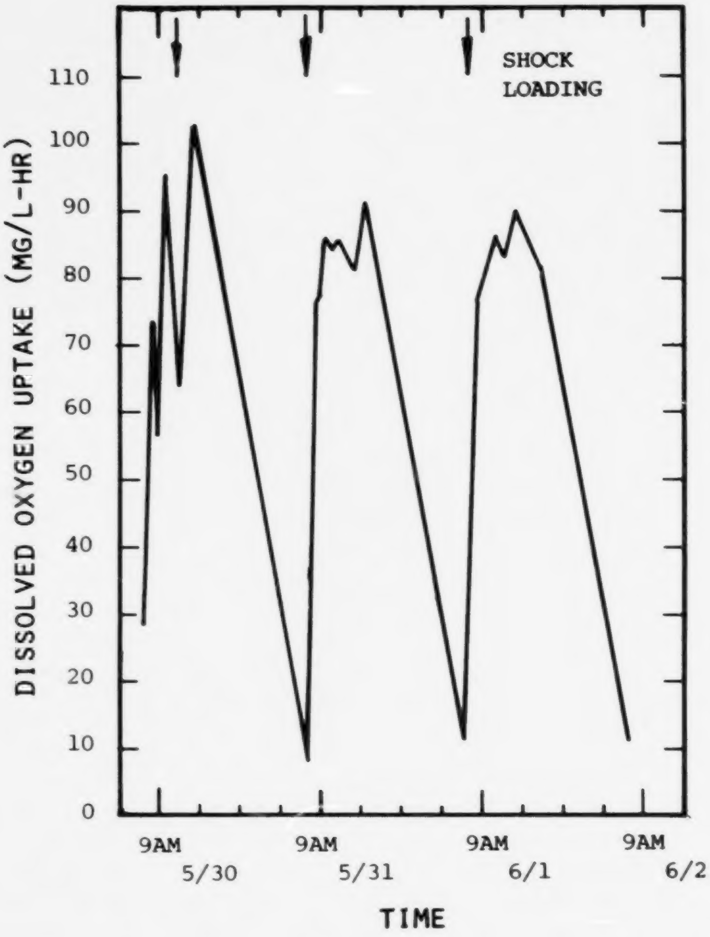

Figure 53. Dissolved oxygen uptake, first compartment, second stage - Marlborough - Phase 3A.

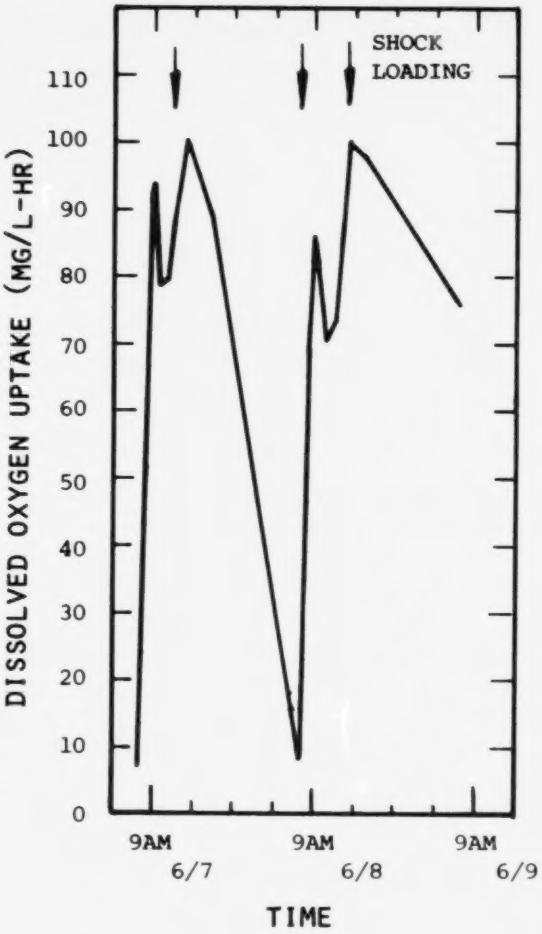

Figure 54. Dissolved oxygen uptake, first compartment, second stage - Marlborough - Phase 3B.

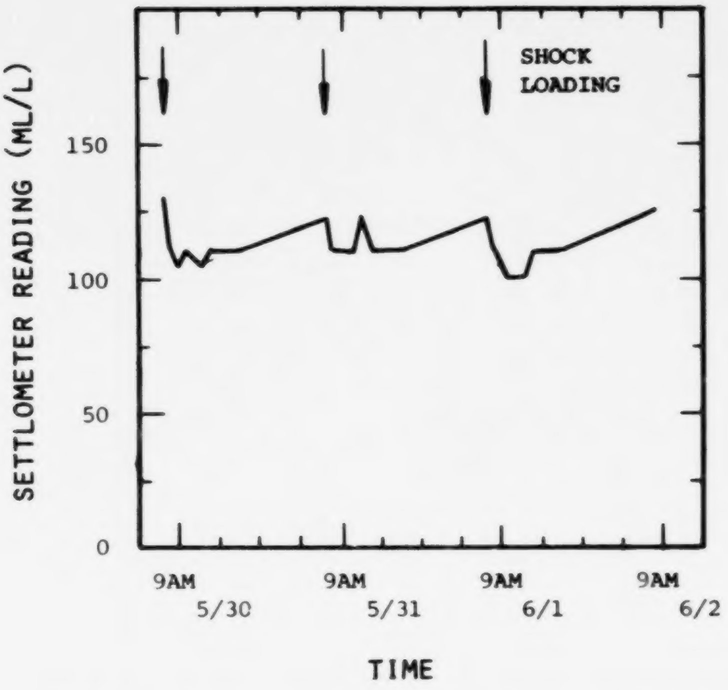

Figure 55. Thirty-minute settlometer, last compartment, second stage - Marlborough - Phase 3A.

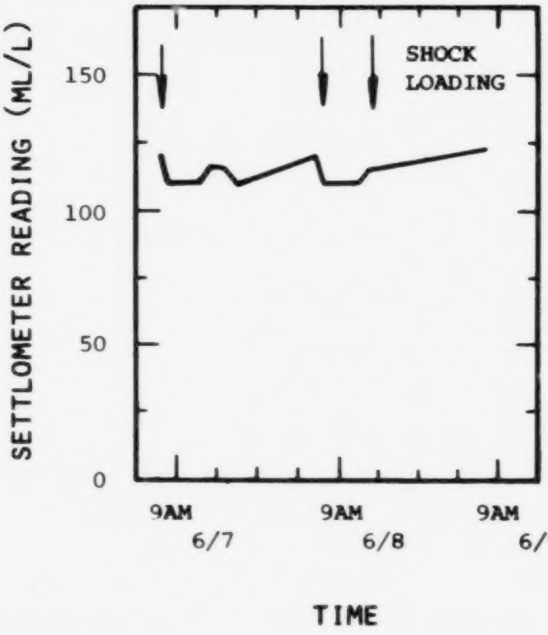

Figure 56. Thirty-minute settlometer, last compartment, second stage - Marlborough - Phase 3B.

SECTION 7

RESULTS AT LOWELL - EXTENDED AERATION

PHASES 1 AND 2

During Phase 1 no septage was fed. Mixed liquor suspended solids stabilized at 4,000 mg/l and the plant achieved excellent solids and organic removals. In Phase 2 septage was fed continuously, except on two occasions. An accidental overfeed and snow storm upset the plant in mid-March 1977. Air compressor and pumps were off for thirty hours and septage was not fed to the plant for a six-day period. The second interruption in septage feed occurred near the end of Phase 2 in early May 1977. On one weekend, a truckload of septage containing a solvent smelling like paint thinner was fed to the plant for a full day. The impact on the plant lasted six days. Effluent, during this upset, was cloudy, had a COD of 640 mg/l, and smelled like the solvent. Microscopic inspection of the mixed liquor indicated that the usual population of higher organisms (rotifers, protozoa, etc.,) was not present, but the presence of well-flocculated solids indicated that the bacterial population had remained viable. The dissolved oxygen uptake rate did not change.

Sewage and Septage Characteristics

During periods when the students occupied the dormitories the sewage was characteristic of a weak to moderate strength waste with an average COD of 373 mg/l. When the students were on vacation the strength of the sewage dropped significantly, with the influent COD averaging only 142 mg/l. Periods of reduced sewage strength occurred from December 22, 1976 to January 14, 1977 and March 14, 1977 to March 20, 1977.

Feed rate and characteristics of septage used for the study at Lowell are shown in Figure 57. COD varied from 3,400 mg/l to 46,000 mg/l. Septage strength declined during the winter months, and increased after mid-March. Haulers stated that much of the pumping done in the Lowell area in the winter is routine periodic work for apartment houses, restaurants, etc.

Food/Microorganism Ratio

Settleability of bacterial flocs in the secondary clarifier acted as a constraint on the maximum permissible solids concen-

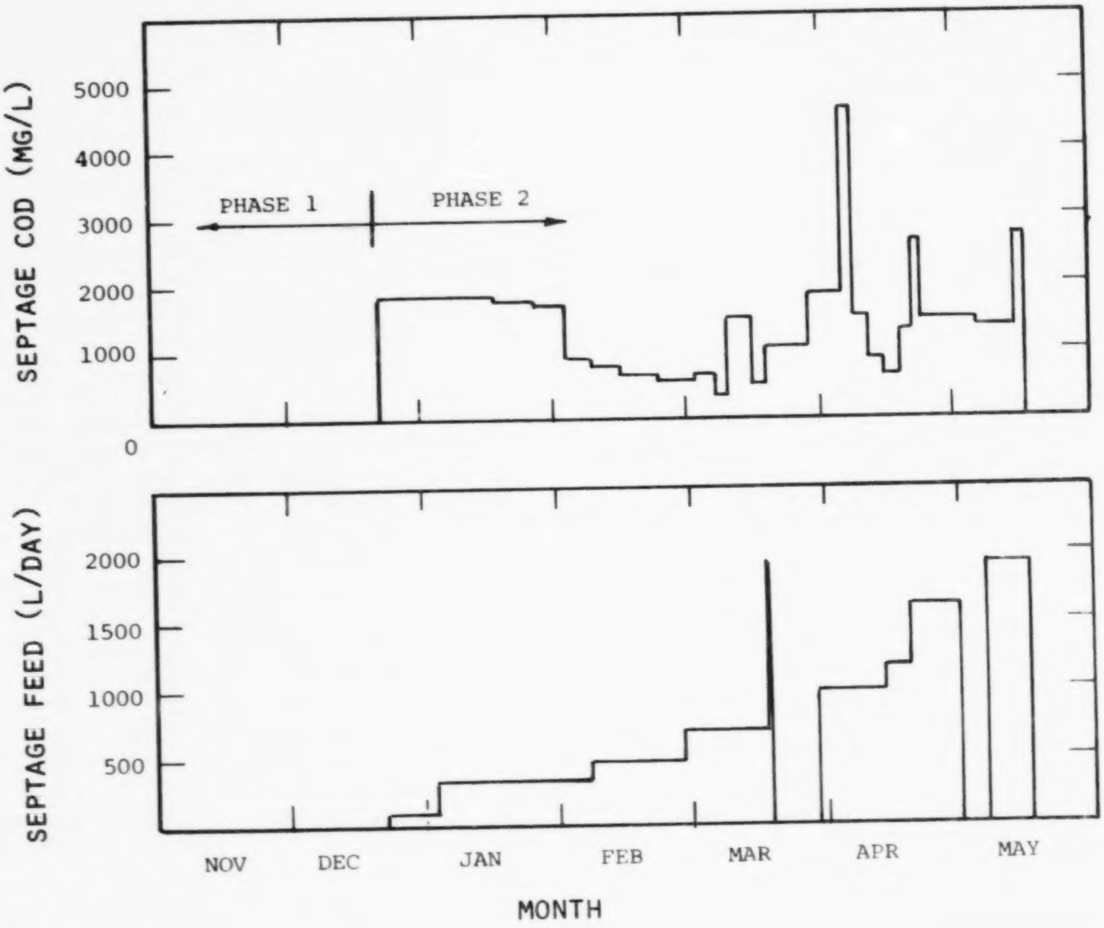

Figure 57. Septage COD and feed rate - Lowell - Extended aeration Phases 1 and 2.

tration carried in the aeration tanks. Figure 58 shows that settlometer values generally follow mixed liquor solids concentration. With this restriction on mixed liquor suspended solids, and the wide variability experienced in the strength of septage, the F/M ratio ranged from 0.05 to 0.15. Plant loading varied from 0.21 to 0.64 kg BOD_5/cu m-day (13 to 40 lb BOD_5/1000 cu ft).

During Phase 2, the introduction of a 3% septage feed doubled the F/M ratio. At maximum septage feed, 6.3%, the F/M ratio was 0.104. If septage had not been added during this test, the ratio would have been 0.033.

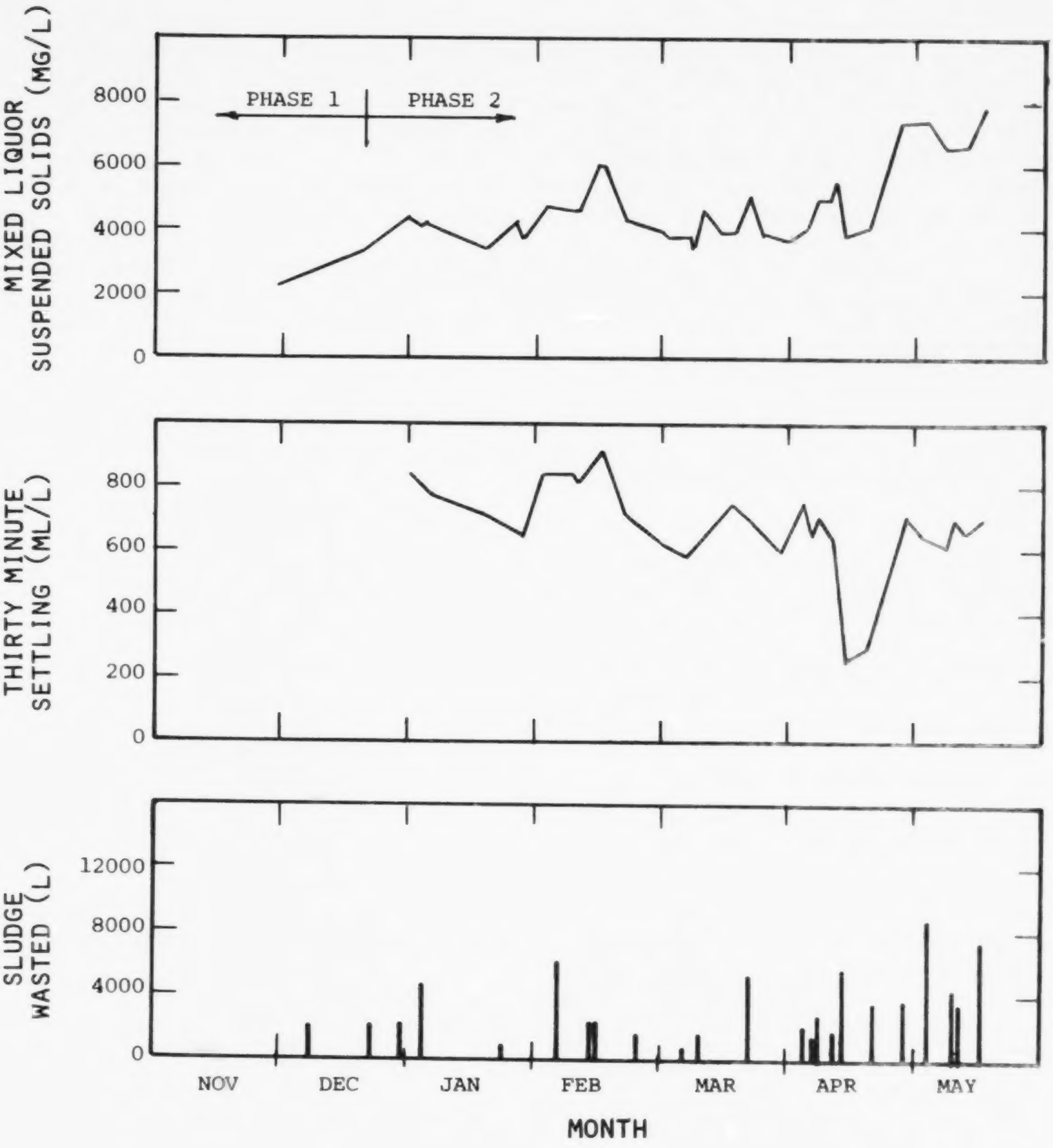

Figure 58. Mixed liquor suspended solids, settleability, and sludge wastage - Lowell - Extended aeration Phases 1 and 2.

Dissolved Oxygen Requirements

Septage addition dramatically increased the demand for oxygen in the aeration tanks. By mid-February, at a septage/sewage feed ratio of 1.5%, the aeration system did not supply enough air to maintain adequate dissolved oxygen levels. The compressor output was increased and conditions improved within hours. The air supply was adequate until the end of the experiment, when once again dissolved oxygen levels were low, this time at a septage feed ratio of 6.3%.

Measured values of oxygen uptake rate compared favorably with oxygen requirements calculated from standard equations. As an example, data are shown in Table 49 for a septage/sewage flow ratio of 3.1%.

TABLE 49. OXYGEN UTILIZATION AT SEPTAGE/SEWAGE RATIO OF 3.1%
LOWELL - EXTENDED AERATION - PHASE 2

Characteristic	Calculated Values
Solids Retention Time, days	20
Mixed Liquor Susp. Solids, mg/l	3,500
Aeration Tank Volume, cu m(gal)	30.3 (8,000)
Septage BOD_L, mg/l	10,000
Septage Feed Rate, cu m/day	0.95
(gal/day)	(250)
Sewage Feed Rate, cu m/day	30.3
(gal/day)	(8,000)
Influent BOD_L, mg/l	300
D.O. Uptake Rate. mg/l-hr-gm	4.5
Effluent BOD_L, mg/l	15
O_2/day, kg/day	11.4
(lb/day)	(25.2)

Theoretical oxygen requirements based upon food utilization and cell wasting:

$$O_2/\text{day} = BOD_L - 1.42 \text{ (Volatile Solids wasted)}$$

$$= 10.6 \text{ kg/day (23 lb/day)}$$

Treatment Efficiency

Septage was treated with sewage in Phase 2 without diminishing effluent quality, at rates up to 3% of the sewage flow. At this septage feed rate, organic loading on the plant was doubled and the plant received twice its design organic loading. At a septage input of 4.4% of the sewage flow rate there was a slight increase in effluent COD and effluent color. Dissolved oxygen in the aeration basin fell below 1 mg/l. Severe disruption occurred after several days at a septage feed rate of 6.3%. The effective treatment range of this plant could have been extended by increasing the air supply, since low dissolved oxygen was the cause of the disruption. The range might also have been extended by wasting more frequently, thereby reducing endogenous (oxygen) requirements. Effluent COD is shown in Figure 59.

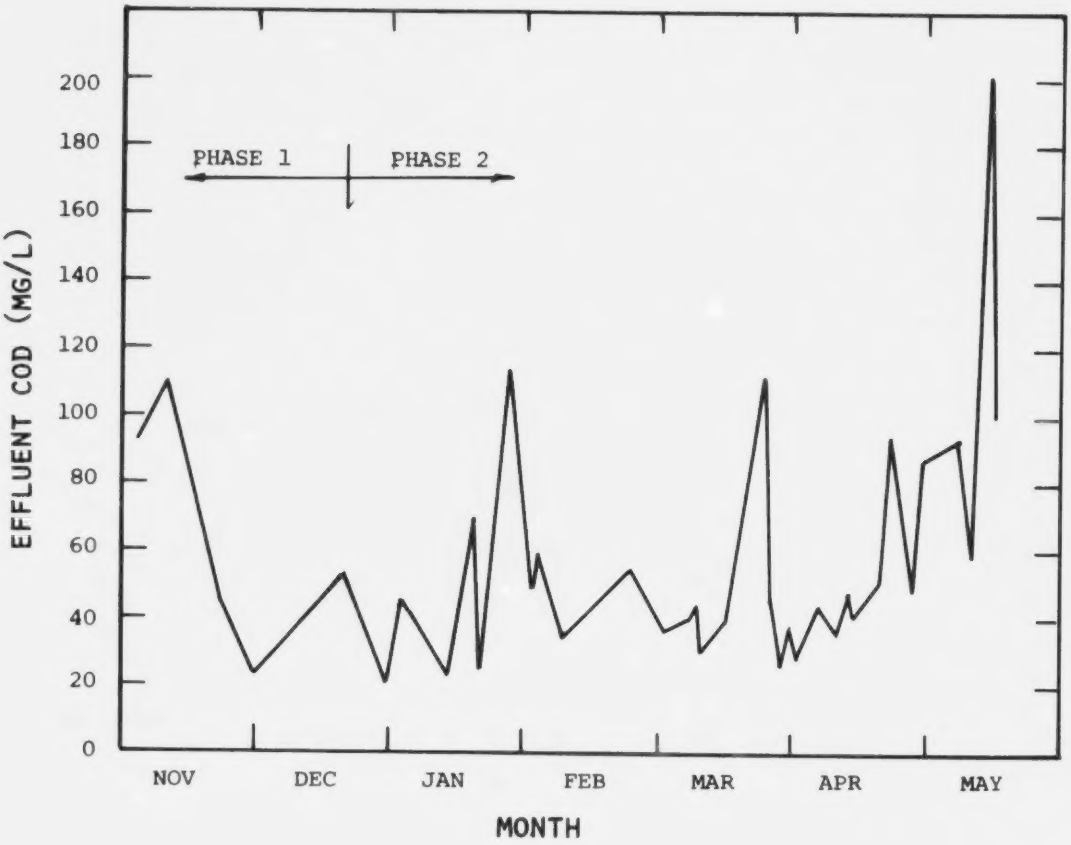

Figure 59. Effluent COD - Lowell - Extended aeration Phases 1 and 2.

Figure 60 shows the impact of the combined sewage and septage influent on treatment efficiency. Effluent COD increased linearly with increasing influent strength. However, the efficiency of COD removal remained almost constant prior to process failure. The plant achieved better than 90% COD removal throughout Phase 2.

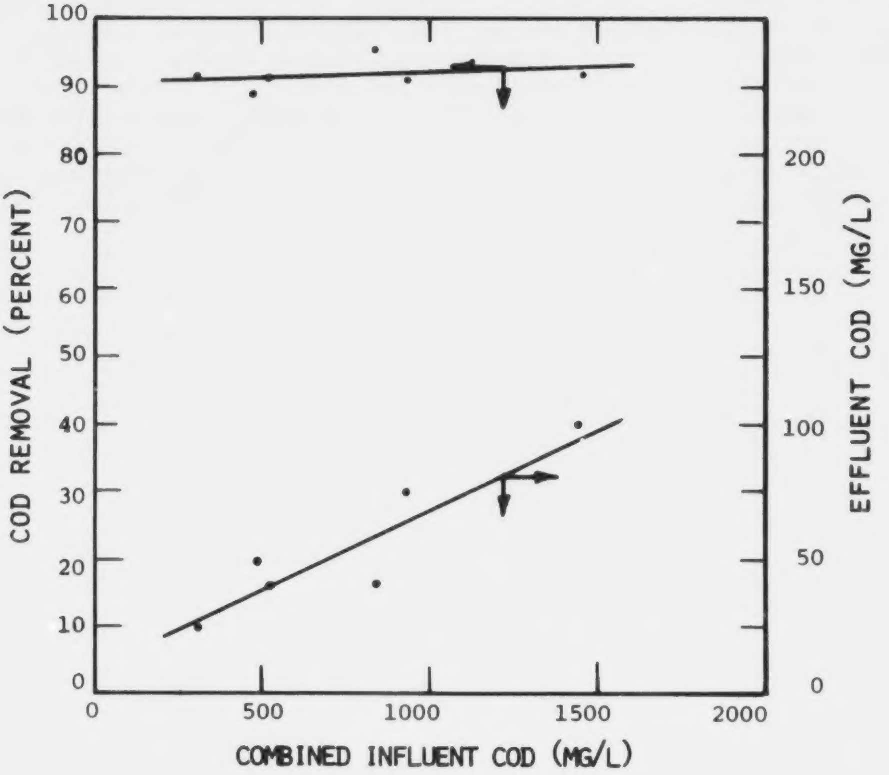

Figure 60. COD removal efficiency - Lowell - Extended aeration Phases 1 and 2.

EXTENDED AERATION - PHASE 3

Phase 3 consisted of two separate shock tests: septage volumes were fed equal to 1.33% and 2.63% of the average daily sewage flow rate. The plant was shock loaded in a period of 5 to 10 minutes in each test.

Mixed Liquor

Mixed liquor suspended solids averaged about 3,000 mg/l during the first shock loading. This was about 500 - 1,000 mg/l less than concentration measured during Phases 1 and 2. The dissolved oxygen uptake rate prior to shocking was about one-half the values measured during the latter stages of Phase 2. This was caused by a reduction in available sewage flow. Dormitories were closed for summer recess and septage had not been fed for some time.

Addition of septage in Phase 3A caused a two-fold increase in dissolved oxygen uptake rate within one hour. The higher rate was maintained for at least six hours after the shock. By the following morning the uptake rate had returned to pre-shock levels. Settleability was not affected by septage addition.

During Phase 3B there was a substantial increase in mixed liquor suspended solids, beginning at 2,800 mg/l and climbing to 3,800 mg/l at the end of the monitored recovery period. Oxygen uptake was low at the start of the test, but one hour after the shock it had again increased significantly. The uptake rate remained higher after 24 hours than it had in the first shock period, but was still lower than its Phase 2 level.

Only a slight loss of settleability occurred at the 2.63% loading.

Oxygen Concentrations

The first aeration basin absorbed the impact of the shock load in both Phase 3 tests. The initial oxygen reduction was simply the result of the introduction of a significant quantity of anaerobic material. Subsequent reduction was caused by the high uptake rate. Dissolved oxygen levels remained high in the second basin. Clarifier dissolved oxygen levels remained high during Phase 3A but fell and were slow to recover in Phase 3B. The most severe lowering of dissolved oxygen occurred within one hour of shocking in both aeration basins, but was delayed in the clarifier until two or three hours after loading. During Phase 3A the septage strength increased each day, but there was little noticeable difference in the dissolved oxygen response. Recovery was essentially complete within four to six hours. In Phase 3B there was a residual effect on the clarifier. Dissolved oxygen levels at corresponding times after shocking were lower on the second day than on the first, and lower yet on the third day. This happened even though the septage strength decreased steadily from the first to the third day.

Effluent Quality

Effluent COD was only marginally affected by septage at the 1.33% loading. It rose to a peak about three to four hours after loading, but returned to very low values twenty-four hours after each Phase 3A shock. The pre-shock COD was 32 mg/l and the maximum value was 48 mg/l (occurring on the first day). As the test proceeded, the maximum level each day decreased, although the septage strength increased. The biological culture readily accepted septage as a food source.

Suspended solids remained below 20 mg/l, with the one exception three hours after shocking on the second day. The concentration rose to 48 mg/l and dropped to 16 mg/l in one hour. Nitrification was not noticeably interrupted during Phase 3A.

Effluent quality was seriously degraded in the second shock loading test, Phase 3B. On the first day of shocking, effluent COD rose from 36 mg/l to a high of 269 mg/l. By the next morning, the level had nearly returned to the previous starting value. On subsequent days, a marked increase in effluent COD was not experienced because the organic loading was significantly decreased as the test proceeded, although the hydraulic loading remained constant. The septage organic loading the first day was 49.6 kg (109 lbs) of COD, on the second day it was 32.4 kg (71.5 lbs), and on the third day, it was 5.8 kg (12.9 lbs). In contrast, the sewage fed during the three days averaged 4.3 kg (9.4 lbs) of COD applied per day.

Effluent suspended solids showed the same trend as COD, rising significantly on the first day, but returning to low levels (generally less than 12 mg/l) for the remainder of the test.

The shock of the first day of Phase 3B inhibited the culture's ability to nitrify; and by the morning of the second day no nitrates were found in the effluent. Nitrates did not reappear until the first morning of the recovery period, and had only risen to about one-third of the starting value at the end of the test.

Shock loading at the 1.3% level did not affect effluent quality even in the first few hours after addition. Increasing the shock to 2.63% did result in deterioration of effluent quality for several hours following the input, but the effect was short lived.

SECTION 8

RESULTS AT LOWELL - CONVENTIONAL MODE OF OPERATION

PHASE 1 - BASELINE FOR COMPARISON

Operating Parameters

During seventeen days of baseline monitoring, the influent sewage flow rate averaged 110 cu m/day (29,100 gpd), the aerator detention time was 6.6 hours, and the clarifier detention time averaged 3.3 hours. The aeration time was typical of conventional practice, but the clarifier detention time was 50% in excess of conventional practice. Students occupied the dormitory facilities for ten days of the Phase 1 period, but were on vacation for seven days in the middle of the period. Process characteristics for the period are shown in Table 50.

TABLE 50. PROCESS CHARACTERISTICS

LOWELL - CONVENTIONAL MODE - PHASE 1

Characteristic	Value
Flow Rate, Q, cu m/day (gpd)	111 (29,300)
Aeration Basin Retention, hrs	6.55
Mixed Liquor Susp. Solids, mg/l	2427
Mixed Liquor Volatile Susp. Solids, mg/l	1893
F/M, kg COD/kg MLVSS-day	0.4
Loading, gm COD/cu m-day (lb COD/1000 cu ft-day)	101 (6.3)
Mean Cell Residence, SRT, days	10
Oxygen Utilization, kg O_2/kg COD	1.22

Influent Characteristics

Influent organic and solids concentrations characterize the waste as weak sewage. Average values for all monitored parameters are shown in Table 51. Both the COD and suspended solids

TABLE 51. INFLUENT AND EFFLUENT

LOWELL - CONVENTIONAL MODE - PHASE 1

	Influent		Effluent	
Characteristic	$\bar{x}$	s	$\bar{x}$	s
COD-Total, mg/l	206	108	50	22
COD-Soluble, mg/l			39	12
Total Solids, mg/l	458	104	379	83
Total Volatile Solids, mg/l	164	65	97	31
Suspended Solids, mg/l	112	81	14	20
Volatile Susp. Solids, mg/l	85	49	10	16
Total Kjeldahl-N, mg/l	18	7.7	5	3.6
Ammonia-N, mg/l	8	3.9	2.1	3.0
Nitrate-N, mg/l	1.5	0.9	8.7	2.1
Total Phosphorus, mg/l	7.3	6.3	2.1	0.4
Alkalinity, mg/l as $CaCO_3$	108	19	60	26
pH	6.8	0.2	6.7	0.2
Temperature, °C	14	1.5	10.7	1.0
Metals, mg/l				
Cadmium	0		0.02	
Chromium	0		0	
Copper	0.11		0.07	
Nickel	0		0	
Lead	0.08		0.09	
Zinc	0.14		0.12	

values were significantly lower when the students were off campus. Ammonia, TKN, and phosphorus concentrations also fell during the vacation period. The system was fed at the rate of 22.9 kg COD-day (50.35 lb/day) or 0.75 kg COD/cu m-day (47.0 lb COD/1,000 ft^3-day).

Effluent Characteristics

The plant functioned well during Phase 1 with effluent COD averaging 50 mg/l, and suspended solids averaging 14 mg/l. Low TKN (5 mg/l) and ammonia nitrogen (2.1 mg/l) levels and moderately high nitrate nitrogen values (8.7 mg/l) indicate that nitrification was nearly complete during this monitoring period.

Phosphorus values were low, averaging 2.1 mg/l. Dissolved oxygen levels were satisfactory during most of Phase 1; they dropped below 1 mg/l on only two occasions. Treatment efficiency averaged 75% based on COD removal and 88% with respect to suspended solids removal. Average effluent values are shown in Table 51.

Mixed Liquor Characteristics

Mixed liquor suspended solids were maintained at an average of 2,430 mg/l, which is typical of conventional operation. Volatile suspended solids averaged 1,890 mg/l and suspended solids were about 78% volatile (See Table 52).

Dissolved oxygen uptake rates averaged 28.9 mg/l/hr or 15.3 mg/l/hr-gram of volatile suspended solids. This value is somewhat lower than those generally found in conventional treatment processes and indicates that the process was lightly fed. The F/M ratio was 0.40 (COD basis) and 0.19 (BOD_5 basis). All mixed liquor samples were taken from the second aeration basin.

The solids retention time was maintained at 10 days by daily wasting 800 gallons of mixed liquor directly from the aeration basin. Settleability remained marginally acceptable throughout this phase, with the half-hour settlometer reading averaging 665 ml/l. The sludge volume index, SVI, was 274 ml/gm. Oxygen concentrations within the aeration basins remained above 1 mg/l except on two occasions when they fell to 0.5 mg/l.

PHASE 2 - CONTINUOUS LOADING

Operating Parameters

The sewage flow rate during the twelve days of Phase 2A averaged 109 cu m/day (28,740 gal/day). This was 1.3% less than the Phase 1 flow rate. Students were in attendance throughout the period and this produced a stronger influent waste. Detention times in the aeration basin and clarifier were the same as those of Phase 1. Phase 2B was conducted over a seven-day period at an average sewage flow rate of 103 cu m/day (27,210 gal/day) or 6.5% less than Phase 1. Process characteristics are shown in Table 53.

Influent Characteristics

Raw sewage COD values were higher during Phase 2A than during Phase 1. Suspended solids concentrations were low, averaging only 78 mg/l. These and other parameters, which characterize the sewage as a weak to moderate domestic waste, are shown in Table 54. Influent sewage imposed an average daily loading on the system of 27.5 kg (60.6 lb) of COD/day or 0.91 kg COD/cu m-day (56.7 lb COD/1,000 cu ft-day).

TABLE 52. MIXED LIQUOR

LOWELL - CONVENTIONAL MODE - PHASE 1

Characteristics	Mixed Liquor	
	$\bar{x}$	s
Total Solids, mg/l	2,436	243
Total Volatile Solids, mg/l	1,727	174
Suspended Solids, mg/l	2,427	285
Volatile Susp. Solids, mg/l	1,893	272
Alkalinity, mg/l as $CaCO_3$	87	21
D. O. Uptake, mg/l-hr	29	13
Dissolved Oxygen, mg/l		
Location A at surface	3.4	1.5
A near bottom	3.2	1.5
B at surface	3.6	1.6
B near bottom	3.4	1.7
C at surface	5.0	2.2
C near bottom	4.8	2.2
Total Kjeldahl-N, mg/l	172	14
Ammonia-N, mg/l	2.9	3.6
Nitrate-N, mg/l	8.9	2.0
Settlometer, 30 minutes, ml/l	666	71
Settlometer, 60 minutes, ml/l	483	53
pH	6.6	0.1
Temperature, °C	12	0.9
Metals, mg/l		
Cadmium	0.03	
Chromium	0	
Copper	0.63	
Nickel	0.10	
Lead	1.43	
Zinc	2.0	

The septage to sewage flow ratio averaged 0.41 percent during Phase 2A and the septage had an average COD value of 13,640 mg/l. Septage increased the COD loading on the plant by 7.5 kg/day (16.5 lb/day) or 0.25 kg/cu m-day (15.4 lb/1,000 cu ft-day). Total organic loading (septage plus sewage) averaged 35.9

TABLE 53. PROCESS CHARACTERISTICS
LOWELL - CONVENTIONAL MODE - PHASE 2

Characteristics	Phase 2A	Phase 2B
Flow rate, Q, cu m/day, (gpd)	814 (28,740)	771 (27,210)
Septage Feed Rate, cu m/day (gpd)	3.4 (120)	6.2 (220)
Septage/Sewage, %	0.42	0.81
Aeration Basin Retention, hrs	6.65	7.0
Mixed Liquor Suspended Solids, mg/l	3,120	2,870
Mixed Liquor Volatile Suspended Solids, mg/l	2,370	2,330
F/M, kg COD/kg MLVSS-day	0.59	0.57
Loading, gm COD/cu m-day (lb COD/1000 cu ft-day)	149 (9.3)	179 (11.1)
Mean Cell Residence, SRT, days	10	10
Oxygen Utilization, kg O_2/kg COD	0.78	0.77

TABLE 54. SEWAGE, SEPTAGE, AND COMBINED INFLUENT
LOWELL - CONVENTIONAL MODE - PHASE 2A

	Sewage		Septage		Combined Sewage and Septage
Characteristics	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$
COD-Total mg/l	253	96	13,643	12,230	309
Total Solids, mg/l	460	74	3,918	1,943	474
Total Volatile Solids, mg/l	190	57	3,038	1,626	202
Suspended Solids, mg/l	78	42	1,756	658	85
Volatile Suspended Solids, mg/l	69	39	1,254	721	74
Total Kjeldahl-N, mg/l	23	0.8	329	89	24
Ammonia-N, mg/l	12	2.7	73	41	12
Nitrate-N, mg/l	1.2	0.4		-	-

(continued)

TABLE 54. (continued)

Characteristics	Sewage $\bar{x}$	Sewage s	Septage $\bar{x}$	Septage s	Combined Sewage and Septage $\bar{x}$
Total Phosphorus, mg/l	5.6	2.1	87	8	5.9
Alkalinity, mg/l as $CaCO_3$	135	10	312	141	136
pH	7.0	0.6	7.2	0.2	-
Metals, mg/l:					
Cadmium	0	0	0.06	0.08	0
Chromium	0	0	0.26	0.38	0
Copper	0.09	0.02	11.4	3.6	0.14
Nickel	0.05	0.02	0.30	0.14	0.05
Lead	0.15	0.13	0.62	0.14	0.15
Zinc	0.07	0.06	2.6	0.14	0.08

kg COD/day (77.1 lb COD/day) or 1.16 kg/cu m-day (72.1 lb/1,000 cu ft-day). This represents a 53% increase over Phase 1.

Total solids loading averaged 50.7 kg/day (112 lb/day) of which 1.8 kg (4 lb) were added by the septage. Septage added only 0.14 kg/day (0.3 lb/day) to the 2.45 kg/day (5.4 lb/day) of nitrogen in the sewage.

During Phase 2B the septage flow was 0.81% of the sewage flow rate. Septage organic, solids, nitrogen and phosphorus levels were, in all cases, higher than for the septage of Phase 2A (See Table 55).

Organic loading averaged 40.4 kg (89.1 lb) COD/day or 1.33 kg/cu m-day (83.3 lb/1,000 cu ft-day), a 77% increase over Phase 1. Of this total 24.9 kg COD/day (54.9 lb COD/day) were added by the sewage and 15.5 kg/day (34.2 lb/day) by the septage. Solids loading was 53.6 kg/day (118 lb/day) of which 18 percent was added by the septage.

The septage increased the total loadings of TKN, ammonia and phosphorus by 11.6%, 6.1% and 22.1%, respectively. As in Phase 2A, the septage increased COD loadings more than any other monitored parameter (62%).

TABLE 55. SEWAGE, SEPTAGE, AND COMBINED INFLUENT
LOWELL - CONVENTIONAL MODE - PHASE 2B

	Sewage		Septage		Combined Sewage and Septage
Characteristics	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$
COD-Total, mg/l	242	117	18,640	15,732	390
Total Solids, mg/l	427	56	11,507	14,292	516
Total Volatile Solids, mg/l	153	45	8,364	9,940	219
Suspended Solids, mg/l	66	31	9,903	13,841	145
Volatile Suspended Solids, mg/l	56	27	7,440	10,020	115
Total Kjeldahl-N, mg/l	24	6.2	346	288	27
Ammonia-N, mg/l	13	5.6	98	79	14
Nitrate-N, mg/l	2.5	1.5	-	-	
Total Phosphorus, mg/l	4.2	0.2	113	15	5.1
Alkalinity, mg/l as $CaCO_3$	119	21	708	349	124
pH	6.6	0.4	6.7	0.5	6.6
Metals, mg/l:					
Cadmium	0		0.24		0
Chromium	0		2.00		0.02
Copper	0.07		820		6.65
Nickel	0.04		0.80		0.05
Lead	0.06		11.20		0.15
Zinc	0.07		57.00		0.53

Effluent Characteristics

Overall treatment during Phase 2A produced an effluent with a lower COD (30 vs. 50 mg/l) and a lower SS (4 vs. 14 mg/l) than during Phase 1. TKN and ammonia were also lower during this phase while nitrate concentrations were slightly higher. Total solids, total volatile solids, phosphorus and alkalinity were almost identical in both phases. The only indication of an adverse effect caused by the septage addition at 0.41% was a decline in effluent dissolved oxygen from 3.0 mg/l in Phase 1 to 0.5 mg/l in Phase 2A. Treatment efficiencies averaged 90% and 95% for COD and suspended solids removal, respectively. Average effluent values are shown in Table 56.

TABLE 56. EFFLUENT
LOWELL - CONVENTIONAL MODE - PHASE 2

	Phase 2A		Phase 2B	
Characteristics	$\bar{x}$	s	$\bar{x}$	s
COD-Total, mg/l	30	8.9	126	152
COD-Soluble, mg/l	22	6.3	26	3.8
Total Solids, mg/l	357	42	410	112
Total Volatile Solids, mg/l	92	27	130	91
Suspended Solids, mg/l	4.0	3.0	52	85
Volatile Suspended Solids, mg/l	3.6	3.0	48	79
Total Kjeldahl-N, mg/l	1.9	0.4	3.5	1.1
Ammonia-N, mg/l	1.3	0.3	1.6	0.7
Nitrate-N, mg/l	9.6	1.5	5.5	1.9
Total Phosphorus, mg/l	2.5	0.5	2.9	0
Alkalinity, mg/l as $CaCO_3$	63	6.7	73	14
pH	6.7	0.2	6.6	0.1
Temperature, °C	12	0.5	13	0.7
Dissolved Oxygen, mg/l	0.5	0.3	0.4	0.5
Metals, mg/l:				
Cadmium	0	0	0	
Chromium	0	0	0	
Copper	0.07	0.02	0.09	
Nickel	0	0	0	
Lead	0.02	0.04	0	
Zinc	0.01	0.04	0.06	

Based upon average effluent total COD and suspended solids values (126 and 52 mg/l, respectively) it would appear that septage significantly degraded effluent quality in Phase 2B.

However, soluble COD values remained at about the same level measured during Phases 1 and 2A. Soluble COD values indicate the system was capable of handling septage at the rates applied during this phase. Based on total COD removal and suspended solids removal, treatment efficiency fell to 67% and 64%, respectively. Dissolved oxygen levels in the effluent were very low, averaging 0.4 mg/l.

Normal organic loadings on conventional activated sludge processes range between 0.32 and 0.64 kg BOD/cu m-day. Assuming a COD:BOD ratio of 2.5:1 for combined sewage and septage, the plant was loaded at the rate of 0.3, 0.46, and 0.53 kg BOD/cu m-day for Phases 1,2A and 2B, respectively. Thus, loadings throughout these three phases covered the typical range.

The Lowell plant performed very well in the conventional mode during Phase 1 and Phase 2A (septage fed at 0.41%). Increasing the loading to 0.81% (Phase 2B) resulted in degradation of effluent quality. This loss of treatment efficiency was caused by overtaxing capabilities of the oxygen transfer system. It is felt that the system would have satisfactorily treated septage at 0.81% if higher oxygen levels could have been maintained. Although treatment efficiency was excellent during Phase 2A, data indicate septage was stressing the oxygen system near its limits.

Lack of primary clarifiers significantly increased organic loadings on the aeration system and led to system overload and effluent quality degradation.

Mixed Liquor Characteristics

Mixed liquor suspended solids concentrations during Phase 2A were one-third higher than those measured during the baseline period (3,170 vs. 2,430 mg/l). This is also true of mixed liquor total solids, total volatile solids and volatile suspended solids concentrations. Alkalinity and TKN in mixed liquor were about 50% higher during Phase 2A than they were during Phase 1, while ammonia was about the same in both phases and nitrates were slightly lower. Table 57 shows average values for Phase 2.

Dissolved oxygen uptake values averaged 35 mg/l-hr or 15.2 mg/l-hr-gram of volatile suspended solids as compared with 29 mg/l-hr or 15.3 mg/l-hr-gram during Phase 1. It is obvious that the increase in overall oxygen uptake rate was due to the higher volatile suspended solids concentration carried in the mixed liquor during Phase 2A. Dissolved oxygen levels averaged 1 mg/l throughout the aeration basins.

Mean cell residence time was held at 10 days. The F/M ratio averaged 0.34 (COD basis) or 0.16 (BOD_5 basis assuming a

TABLE 57. MIXED LIQUOR
LOWELL - CONVENTIONAL MODE - PHASE 2

Characteristics	Phase 2A $\bar{x}$	Phase 2A s	Phase 2B $\bar{x}$	Phase 2B s
Total Solids, mg/l	3,230	438	3,190	413
Total Volatile Solids, mg/l	2,440	430	2,525	286
Suspended Solids, mg/l	3,170	276	2,870	396
Volatile Suspended Solids, mg/l	2,370	450	2,330	365
Alkalinity, mg/l as $CaCO_3$	129	46	145	33
D.O. Uptake, mg/l/hr	36	7	43	21
Dissolved Oxygen, mg/l:				
Location A, at surface	1.1	0.4	2.4	2.4
Location A, at bottom	0.8	0.3	2.2	2.4
Location B, at surface	1.0	0.3	2.3	2.3
Location B, at bottom	0.9	0.3	2.1	2.3
Location C, at surface	1.2	1.4	0.9	1.2
Location C, at bottom	1.0	1.3	0.7	1.2
Total Kjeldahl-N, mg/l	240	39	221	29
Ammonia-N, mg/l	2.4	0.9	2.3	1.5
Nitrate-N, mg/l	6.8	3.7	3.6	2.2
Settlometer, 30 min.,ml/l	686	124	880	16
Settlometer, 60 min.,ml/l	514	104	740	44
pH	6.5	0.3	6.5	0.2
Temperature, °C	13	0.5	14	0.5
Metals, mg/l:				
Cadmium	0.03	0.01		
Chromium	0.50	0.50		
Copper	1.64	0.41		
Nickel	0.09	0.02		
Lead	1.22	0.08		
Zinc	9.03	9.58		

COD/BOD_5 ratio of 2:1 for the combined influent and septage). This loading was lower than that of Phase 1 even though septage was added, because of the increased mixed liquor suspended solids carried during Phase 2A. Loadings were at the low end of recommended values for conventional activated sludge processes.

Sludge settleability was acceptable with the one-hour settlometer reading, averaging only 6% above Phase 1 values. The SVI averaged 216 ml/gram. However, as Phase 2A progressed, settleability declined. The clarifier had at times (prior to this phase) shown a tendency to unload solids. This was not a continuous happening, but occurred on some days for short periods of time. The effluent suspended solids data indicate that the clarifiers did not unload solids during this phase, but the settlometer data indicate it may have been tending this way. Whether septage was the cause is not discernable from the data.

During Phase 2B, mixed liquor suspended solids (2,870 mg/l) were midway between Phase 1 and Phase 2A average values. The volatile suspended solids were about the same as for Phase 2A, 2,330 mg/l. Alkalinity was again higher for this phase than for Phase 1. Ammonia nitrogen remained approximately the same as in previous phases, however, nitrate levels fell to approximately one-half those of Phase 2A and about 40% of Phase 1 values. TKN values were lower than Phase 2A as, would be expected, since both the total solids and suspended solids concentrations were less. It is interesting to note that the ratio of total solids to TKN averaged 14.2, 13.5 and 14.4 for Phases 1, 2A and 2B, respectively. Values are shown in Table 57.

Dissolved oxygen uptake rate averaged 43 mg/l-hr or 18.5 mg/l-hr-gram VSS. This rate is about 20% higher than in the previous two phases and was due to an elevated food concentration. However, the standard deviation of this data was three times that of Phase 1 and 50% higher than in Phase 2A.

Mean cell residence time was held at 10 days. The F/M ratio was 0.53 based upon COD and 0.25 based upon BOD_5. This loading was within the range recommended for conventional processes and was the highest applied during continuous feeding operations.

Throughout this phase dissolved oxygen levels remained near 1 mg/l or less, except on occasions when the influent pump clogged and sewage feed slowed. It is apparent that this situation occurred on two of the nine days of the test. Oxygen levels were approximately the same as those of Phase 2A and much lower than during Phase 1. This indicates that the pilot plant may have been approaching its oxygen transfer limitation.

Sludge settleability began to degrade during Phase 2B with the one-hour settlometer reading averaging 740 ml/l. This value is much higher than the 514 ml/l of Phase 2A and 483 ml/l for Phase 1. SVI for this phase averaged 307 ml/gram.

PHASE 3 - SHOCK LOADING

Influent - Sewage Plus Septage

Phase 3 began two weeks after the completion of Phase 2B. In the interim sewage feed was maintained but septage was withheld. Prior to initiating Phase 3, the process began to deteriorate because of severe influent pump plugging problems. This condition resulted in periods of reduced feed or no feed at all. Loadings became erratic and unknown and the culture suffered substantially. Settleability was poor and on several occasions the blanket in the clarifier rose to the surface and unloaded solids over the weir.

The influent COD averaged 378 mg/l and that of the septage, 23,600 mg/l. The process was shock loaded with 41.3 kg (91 lb) of sewage COD combined with 26.8 kg (59 lb) of septage COD, on each of three days. The total solids loading was 58.6 kg (129 lb) per day. Septage contributed 49.9 kg (110 lb) and sewage 8.6 kg (19 lb) each day. It took one hour to feed each shock load. During the one-hour period the loading on the system was equivalent to 644 kg (1,420 lb) of COD per day and 212 kg (468 lb) total solids per day.

The raw sewage was typical of a moderate strength domestic waste. Septage volumetric loading represented 1.04 percent of the daily flow on each of the three days. Values are shown in Appendix Tables M-1 and M-2.

Effluent Characteristics

A composite sample collected during the twenty-four hours preceding the first day's shock had a suspended solids concentration of 114 mg/l, indicating that clarifier operation was still unbalanced. After loading on the first day, hourly samples showed low suspended solids (15 mg/l or less) for the next three hours rising to 40 mg/l in the fourth hour and 60 mg/l in the sixth hour. However, they had returned to 15 mg/l the following morning. Effluent total COD showed the same trend, but soluble COD remained low throughout, as did the BOD values.

On the second day, suspended solids remained low for two hours following the shock and then rose to between 700 and 800 mg/l, falling to 136 mg/l the next morning. They continued to fall until the sixth hour after shocking on the third day. At this time the blanket in the clarifier again reached weir level and spilled solids in the effluent. Total COD again followed the same trend with soluble COD remaining low throughout, averaging 32 mg/l with a standard deviation in the twenty samples of 11.5 mg/l.

Nitrification was severely inhibited. Prior to shocking, the nitrate concentration was 9.0 mg/l and fell steadily throughout the first and second days to a low of 0.7 mg/l. Recovery began on the morning of the third day, but again dropped to the previous lows two to three hours after loading. Nitrates recovered to only 1.7 mg/l three days after termination of the shock loading.

Unfortunately, phosphorus levels were not determined on the first day of the shock. Beginning on the second day, effluent phosphorus levels were less than 1 mg/l and showed a definite influence on the septage within three hours rising to 15.5 mg/l. On the third day, wash through of phosphorus was continuing and again the septage increased effluent values noticeably within three hours.

Alkalinity and pH remained constant throughout the test. Variations in TKN were similar to changes in COD and suspended solids. Process disruption was severe at the 1% septage feed rate of this phase. This was due to the poor condition of mixed liquor and limitations in oxygen transfer.

Mixed Liquor Characteristics

Mixed liquor suspended solids concentration dropped from 1,670 mg/l at the beginning of the test to 1,240 mg/l at the end of the three-day shock period. Compared with conventional operation these values are low.

Dissolved oxygen uptake rates were stimulated by the addition of septage. On the first day, the uptake rate climbed from 8.2 mg/l-hr (5.0 mg/l-hr-gram VSS) to a high of 41.1 mg/l-hr (25.3 mg/l-hr-gram VSS). The pre-shock value was characteristic of a very lightly loaded system. The latter value is typical of conventional process return sludge. The second and third day values rose to the same maximum value of 32.6 mg/l-hr-gram VSS.

The one-hour settlometer readings averaged 640 ml/l. While this value is typical of some of the other phases, it is a poor rate at low mixed liquor suspended solids concentrations. The SVI averaged 522 ml/gram, indicative of a poorly settling sludge. In all phases of the conventional loading study, SVI values were well above the 100 ml/gram level usually considered desirable.

Before initiating Phase 3, aerators were adjusted to direct the major air flow to the first aeration basin. This was done in anticipation of a heavy oxygen demand in the first basin. As a result, when the shock loads were applied, dissolved oxygen levels in the first basin were reduced to between 2 and 3 mg/l within one hour and then began to recover. However, the second basin dropped to below 1 mg/l within one hour and remained at this low level until run completion with one exception on the third morning. Clarifier dissolved oxygen concentrations remained under 1 mg/l throughout the test and in most cases were zero. It is concluded that the 1% loading in Phase 3 produced severe oxygen depletions in the plant.

SECTION 9

MICROBIOLOGY

MICROBIOLOGICAL STUDIES

Microscopic analyses were performed in all phases of the monitoring program at both Medfield and Marlborough. At Medfield microbiological communities were identified in mixed liquor, return sludge, and in secondary effluent. Unicellular algae and protozoan species and microscopic metazoan species were enumerated in a Sedgwick-Rafter cell.

Organisms were not counted during the Marlborough study. The predominant forms and relative abundance of particular indicator groups were noted. In addition, floc characteristics were observed and recorded.

Analyses of Medfield samples were conducted by faculty and graduate students in the University of Lowell, Department of Microbiology. Marlborough samples were analyzed by a biologist with wastewater treatment plant operating experience.

MEDFIELD - MICROSCOPIC STUDIES

Medfield microfauna consisted of various protozoan types. The "Micro-flagellates" found in mixed liquor and return sludge were designated as flagellates with characteristic cell sizes of 5 to 20μ range. The term "macroflagellate" was used to classify flagellated protozoans with cell sizes in the 30μ and greater size range. Euplotes and Colpoda were frequently seen free swimming ciliates, both in mixed liquor and return sludge. Colpoda were occasionally seen in secondary effluent. Ciliates of small size, less than 20μ , were lumped under the classification of microciliates. Lionotes, another ciliate, were also seen in mixed liquor and return sludge. This species appears to be quite sensitive to alterations in the treatment plant loading and showed acute sensitivity to shock loading. Vorticella, a sessile ciliated protozoan, appeared in low to moderate numbers in mixed liquor and return sludge, and were very infrequently observed in the effluent stream. Suctorians, a less frequently found stalked ciliate, have similar distribution to the vorticella, and like vorticella, indicate a mature stable community. Rotifers, a metazoan species, similarly indicate a more mature stable community and, like lionotes and the sessile ciliates, show sensitivity to insult. Sarcodinian protozoa were occasionally observed, but these amoeboid forms were not recorded due to the great difficulty in distinguishing the population density within the sludge particulates. Armored amoebas were similarly overlooked, as the difficulty in distinguishing live individuals from dead individuals led to the decision to eliminate them from practical consideration. Occasional vorticella, nematodes and rotifers were recorded in the effluent.

Effluent flora was categorized by green filamentous algae: scenedesmus, a non-motile green algae, and pennate and naviculate diatoms. Large spirochetes were seen with moderate frequency.

Species number, numbers of individuals within each species and total number of individuals in counted samples provided input for computerized calculation of the Shannon Weiner Species Diversity Index, defined as:

$$\bar{H} = -\Sigma \, (n_i/N) \log (n_i/N)$$

where n_i = the number of individuals of the i^{th} species

N = total number of individuals in a sample.

A high $\bar{H}$ value is indicative of a diverse, stable, healthy community.

Results

Plots were made of the number of species, S; total number of individuals, N; and species diversity, $\bar{H}$, of each of the samples observed. Figures 61 through 71 show the relationships of these parameters over the time course of the study. Data on species composition and distributions within samples are provided in the appendices on data sheets entitled Microbiological Indices.

Medfield - Phase 1

Phase 1 monitoring conducted from August 25, 1977 through September 12, 1977 provided baseline data under conditions of normal operations. Control phase operations showed inherent levels of fluctuation in the measured parameters and provided indication of the effects of normally experienced variations in flow rate and sewage concentration.

Mixed liquor data indicated a species diversity index, $\bar{H}$, which centers about a mean of 1.85; number of organisms in the samples average 72 individuals per 1 ml sample distributed within an average of seven species for the thirteen days of sampling microorganisms. These data, presented in Figure 61, show an initial depression in diversity, the cause of which may have been the septage cleanout operation, which preceded Phase 1. A major holiday weekend, September 3 through 5, coincides with a lowering of numbers and increase in species diversity. These aberrations show subsequent recovery over the next four days. A rain storm of September 9, 1977, which increased flow rate of raw sewage by 39%, is associated with a second reduction in diversity. Of particular interest here is the behavior of population densities of the ciliates, euplotes and colpodas. Return sludge (Figure 62) shows similar aberrations following the holiday period and the rain storm. Secondary effluent as monitored over the period appeared to be more stable (Figure 63). Data are shown in detail in Appendix Table B-6.

The relative sensitivity of normal, non-septage-loaded conditions in the Medfield plant may be a result of the relatively light sewage load received at the plant.

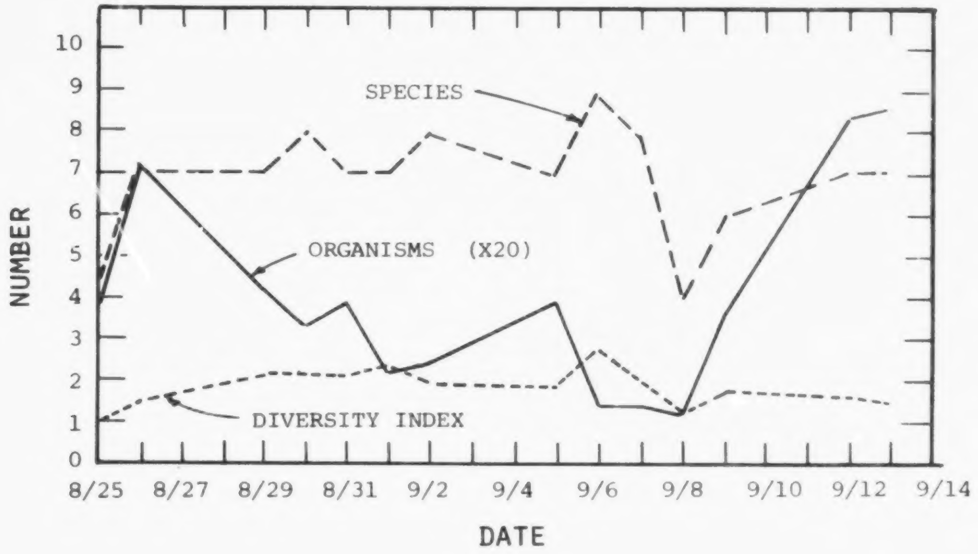

Figure 61. Microbiological indices, mixed liquor - Medfield - Phase 1.

Medfield - Phase 2

Phase 2 studies of mixed liquor, return sludge and secondary effluent (Figures 64, 65 and 66) show a consistent response pattern. Mixed liquor shows an average species number of

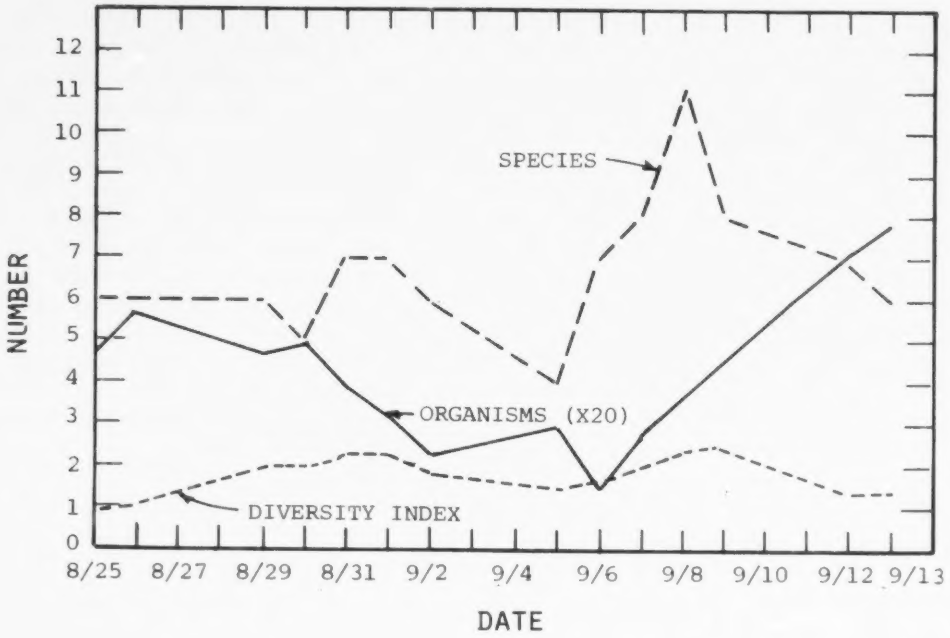

Figure 62. Microbiological indices, return sludge - Medfield - Phase 1.

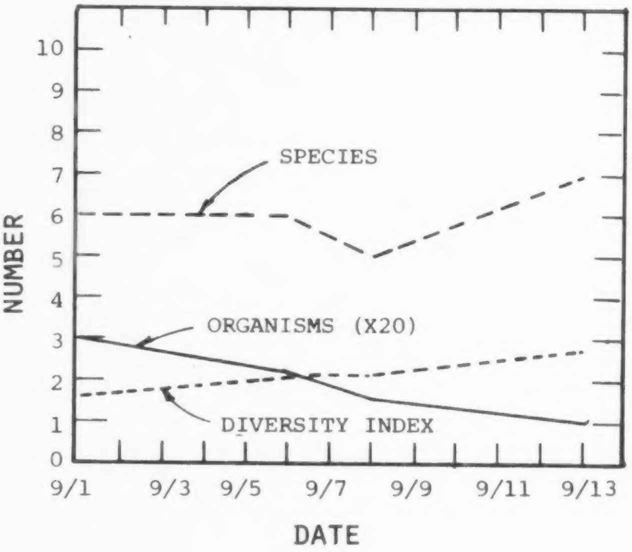

Figure 63. Microbiological indices, effluent - Medfield - Phase 1.

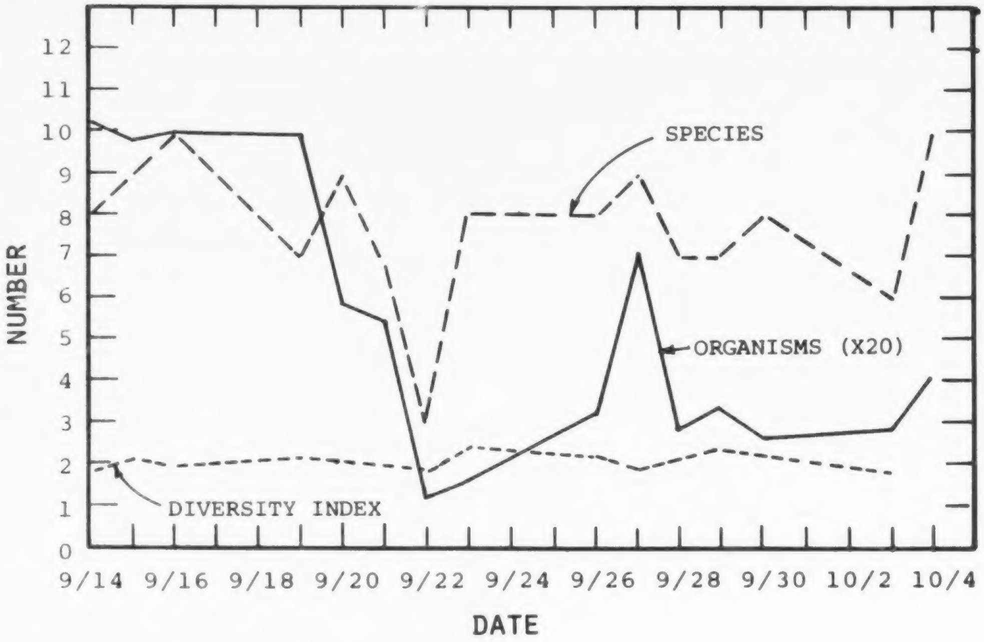

Figure 64. Microbiological indices, mixed liquor - Medfield - Phase 2A.

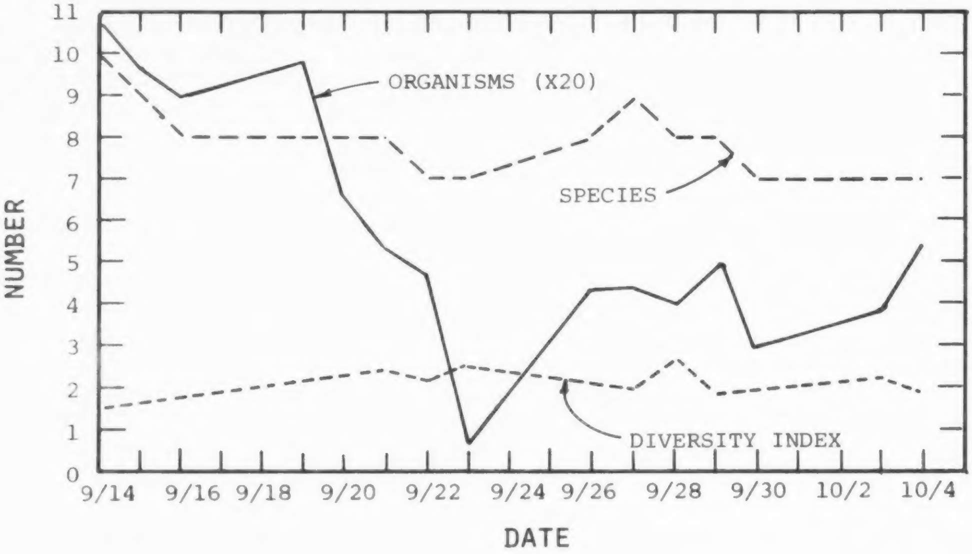

Figure 65. Microbiological indices, return sludge - Medfield - Phase 2A.

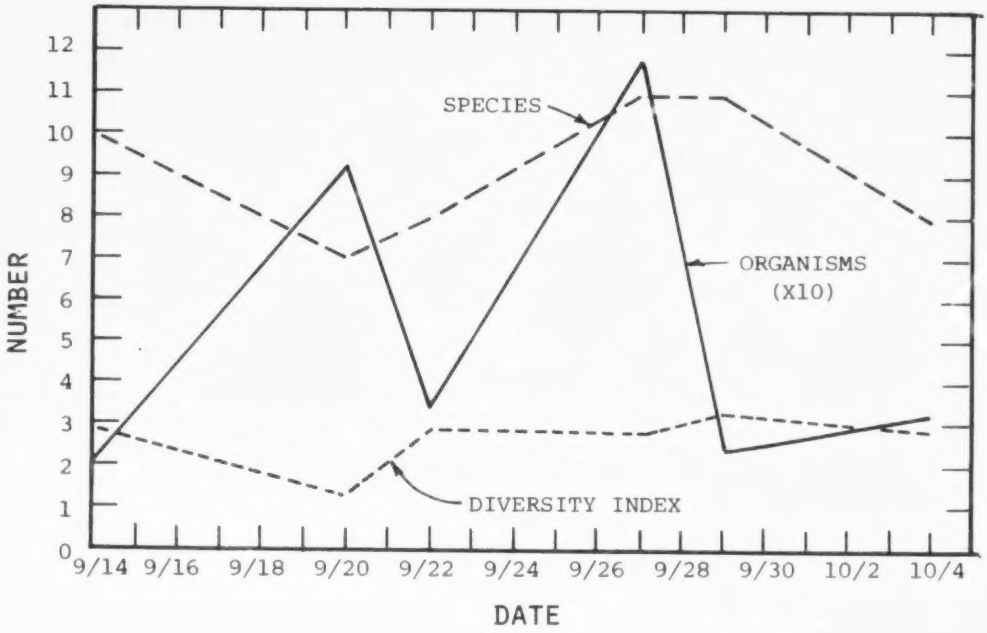

Figure 66. Microbiological indices, effluent - Medfield - Phase 2A.

7.7 with a standard deviation of 1.75 throughout the course of Phase 2 constant loading. The species diversity averaged 2.01 (standard deviation was 0.37), and the number of organisms averaged 107 organisms per ml with a standard deviation of 65.5. This high standard deviation is the result of step-like changes in the number of individual organisms per sample. Data are presented in Appendix Tables C-7 and D-8.

While number of species is quite constant, a major shift in the numbers of individuals appears on September 20 followed by a slight decline on September 21 and a precipitous decrease on September 22. Species most conspicuously affected are the ciliates and rotifers. Changes in fauna appear to be associated with a temperature change of over 3°C over September 19th to 20th, followed by a shut-down on September 23 of the return sludge pumping operation. Complete recovery of the community was not observed as the colpoda and euplotes species did not reestablish former population densities. It is apparent, however, that the mixed liquor community assumed a new, stable equilibrium composition as the newly established equilibrium persisted for the remaining ten days of the study. Return sludge and effluent communities showed similar changes over the septage addition period. These microbiological data appear to correlate quite closely with certain chemical parameters (particularly nitrogen data).

In Phase 2B, little change was observed in either mixed liquor or in the effluent. Figure 67 indicates the relative stability of the situation.

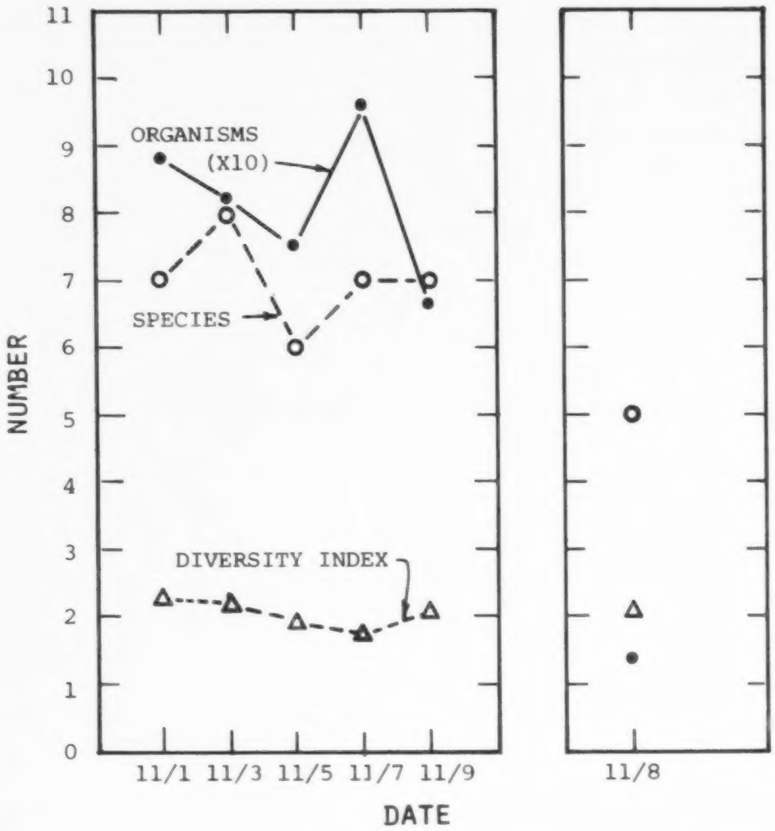

Figure 67. Microbiological indices, effluent - Medfield - Phase 2B.

Medfield - Phase 3

During Phase 3A, microbiological indicators were monitored intensively over the time course of the daily loadings. Over the 24-hour period the typical response was one of reduction in overall numbers of organisms, reduction in species, but no significant reduction in species diversity. Slight trends toward recovery in numbers and species were observed, but full recovery was observed only once and only in species number (Figure 68). The reduction in species and numbers with the maintenance of species diversity levels around 2 indicates

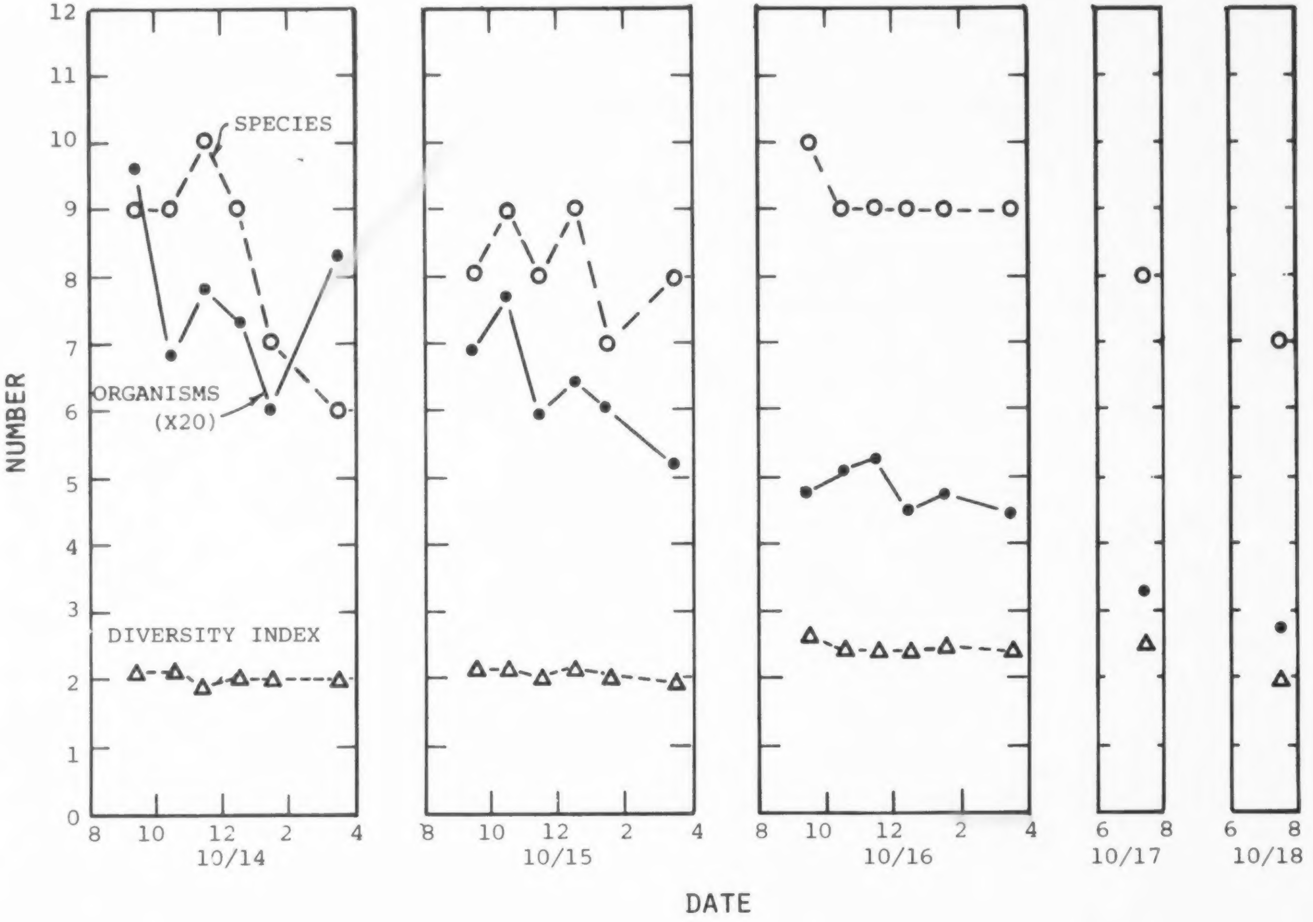

Figure 68. Microbiological indices, mixed liquor - Medfield - Phase 3A.

that the more common species were affected most adversely by the process. Lionotes were observed to be very sensitive to shock loading and decreased from an initial density of 50.5% of the total population to an ending density of 5.5% of the total. This species demonstrated a strongly regressive decrease over the course of the shock loadings. Rotifers and spirochetes showed less intense regression rates.

Phase 3 effluent showed daily reductions in number, species and diversity. An interesting occurrence in this phase was a reduction in the floral species composition. Green algae, scenedesmus and the pennate and naviculate diatoms were eliminated. The fauna constituents of the effluent did prevail, however. Figure 69 illustrates this. Biological parameter trends in basin 1, the receiving basin, show a similar pattern as illustrated in Figure 70.

In Phase 3B, higher concentrations of septage applied daily showed equivalent results with daily decreases in all parameters followed by recovery toward the end of the day (Figures 71 and 72). This loading program did not appear to alter significantly the communities' abilities to recover from septage insult. Secondary effluent shows similar recoveries. Appendix Tables E-9 and F-7 show the test results.

MARLBOROUGH MICROSCOPIC ANALYSES

Floc characteristics and indicator organism populations were monitored during the baseline and septage addition periods at Marlborough. Six parameters were used to describe floc characteristics: color, size, texture, edge condition, interspace clarity and the presence of filamentous forms. Microorganism species used as indicators of process performance and sludge age were free swimming and stalked ciliates, flagellates and rotifers.

Floc Characteristics

A "good" quality sludge in a conventional activated sludge process usually has floc that is small to medium in size, fairly uniform in shape with well defined edges, slightly granular in texture, and golden brown in color. The interspaces between the floc are clear, and filamentous organisms, while generally present, are not overly abundant. A good sludge settles slowly, occupying about 350 ml in a settlometer after thirty minutes of settling, and produces an effluent low in suspended solids and BOD.

An overoxidized or "old" sludge tends to be characterized by small granular flocs of high density with jagged edges, irregular shape, and a dark grey color. It has a low respiration rate and settles very rapidly in the secondary clarifier.

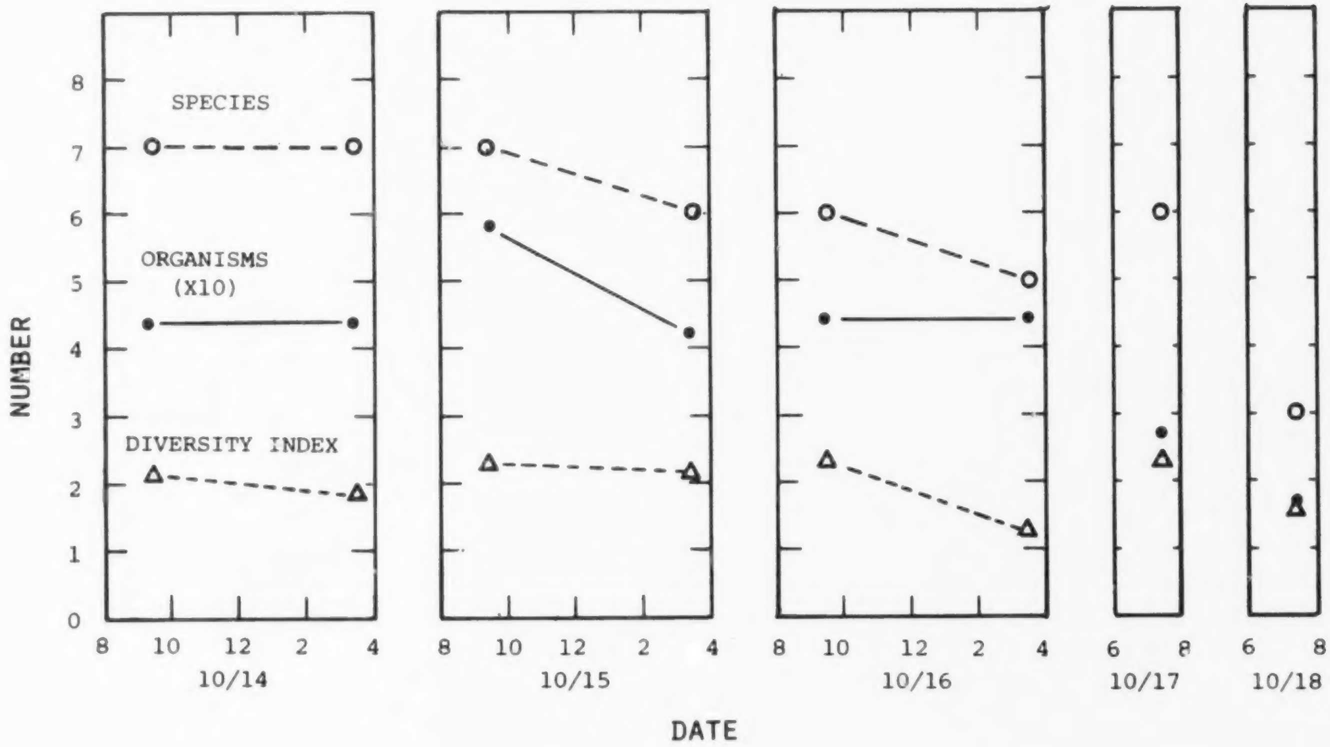

Figure 69. Microbiological indices, effluent - Medfield - Phase 3A.

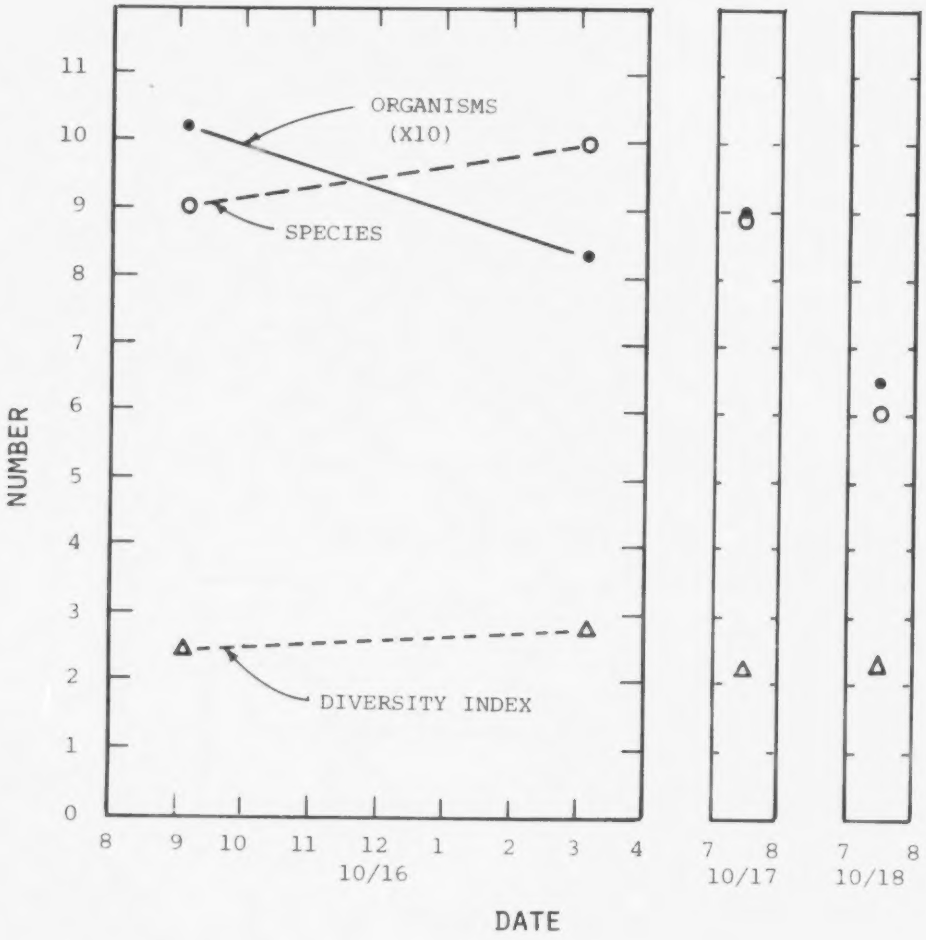

Figure 70. Microbiological indices, mixed liquor - Medfield - Phase 3A.

In the conventional process the formation of an old sludge generally results in a turbid effluent with a high SS concentration. Typical causes of old sludge are excessive aeration tank detention time, low influent organic loadings and insufficient wasting.

A highly filamentous floc is indicative of a potential sludge bulking condition. The occurrence of excessive filamentous growth can result from various adverse conditions in the process. These include organic and hydraulic overloads, too long or too short a sludge age, dissolved oxygen problems, pH problems, toxicity, and industrial shock loadings.

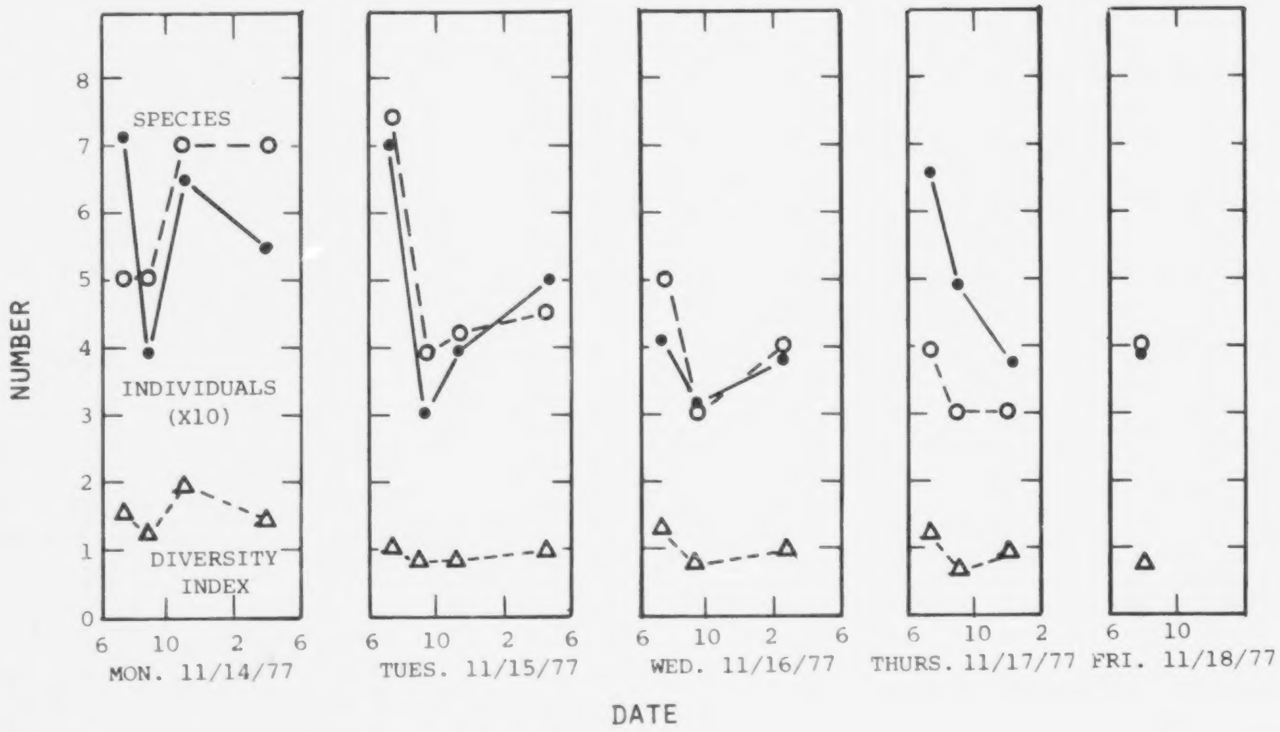

Figure 71. Microbiological indices, mixed liquor - Medfield - Phase 3B.

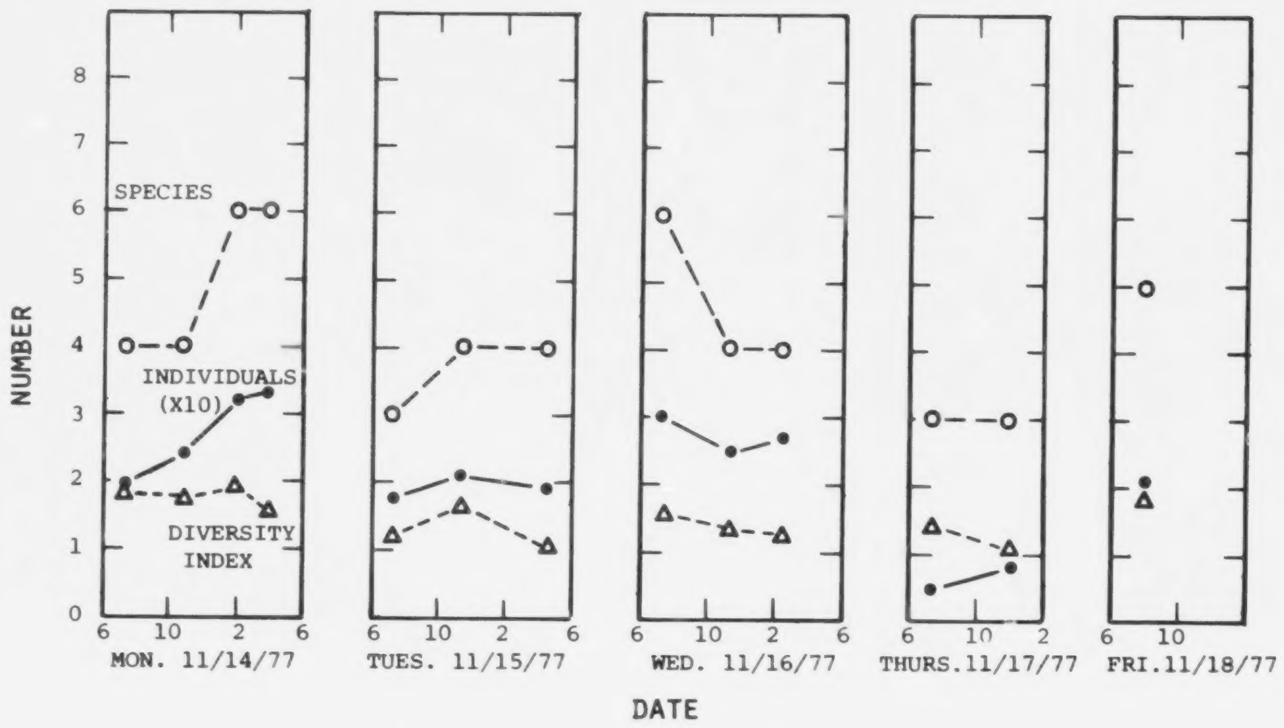

Figure 72. Microbiological indices, secondary effluent - Medfield - Phase 3B.

Microorganisms

A "good" activated sludge from the conventional process operated at a mean cell residence time of five to ten days usually has representatives from many protozoa species. There is generally a high concentration of both the free swimming and stalked ciliates: the latter is usually the predominant form. Free swimming flagellates are generally present in relatively high numbers. These are found in greater abundance in unstabilized sample sludge, i.e., short mean cell residence time. Rotifers may or may not be present. Their presence is usually indicative of the highly stable conditions associated with a long mean cell residence time.

Non-ideal or adverse process conditions create a variety of changes in the relative distribution of indicator groups. A young sludge condition will cause a predominance of the free swimming forms, both ciliates and flagellates. An old, well stabilized sludge may be entirely lacking in the free swimmers and have an abundance of stalked ciliates and rotifers. Changes in organic loading can disrupt the distribution of organisms.

Phase 1 - Results

In the first stage aeration tanks, floc characteristics and indicator organism populations were typical of a well-run conventional process with a slightly long mean cell residence time. The results are shown in Table 58. The floc was well defined, medium to small in size, slightly granular in texture, grey-brown in color, and contained few filamentous forms. The predominant indicator group was the stalked ciliated protozoa. Free swimming flagellates were consistently present in sufficient numbers to cause turbidity in the floc interspaces, but were not in the abundance usually found in a young sludge. Free swimming ciliates were very few in number, and no rotifers were detected.

In both compartments of the nitrification process (Tables 59 and 60) floc characteristics and organism populations indicated a highly stabilized condition. In the first compartment floc was very small and granular, with jagged edges and a golden brown color. The interspaces were clear but the floc was highly filamentous. In the last compartment floc conditions were very similar to the first except that filamentous forms were even more numerous. During the course of the Phase 1 study, the quantity of filamentous forms slowly decreased. Their presence in the sludge mass did not appear to cause any adverse effects in the process and probably helped by slowing the settling rate of what would otherwise have been a very rapidly settling sludge. The predominating indicator group

TABLE 58. MIXED LIQUOR MICROBIOLOGICAL INDICES AND FLOC CHARACTERISTICS - MARLBOROUGH FIRST STAGE

	PHASE			
	1	2A	2B	3
Floc Characteristics				
Color	Grey	Grey-Brown	Yellow-Grey Brown	Yellow-Grey Brown
Size	Small to Medium			
Texture	Fairly Granular			
Edges	Well Defined			
Interspaces	Slightly Turbid			
Filamentous	Few			
Species				
Free Swimming Flagellates	Numerous	Few	Fairly Numerous	Numerous
Free Swimming Ciliates	Few			
Stalked Ciliates	Predominant			
Rotifers	None	None	Few	Few

TABLE 59. MIXED LIQUOR MICROBIOLOGICAL INDICES AND FLOC CHARACTERISTICS - MARLBOROUGH SECOND STAGE - FIRST COMPARTMENT

	PHASE			
	1	2A	2B	3
Floc Characteristics				
Color	Golden Brown			
Size	Very Small			
Texture	Very Granular			
Edges	Jagged	Jagged	Fairly Well Defined	Fairly Well Defined
Interspaces	Clear			
Filamentous	Numerous		Fairly Numerous	

(continued)

TABLE 59. (continued)

	PHASE 1	PHASE 2A	PHASE 2B	PHASE 3
Species				
Free Swimming Flagellates	Few - - - -	Few - - -	Few - - -	Fairly Numerous
Free Swimming Ciliates	- - - - - - - - - Few - - - - - - - - - -			
Stalked Ciliates	- - - - - - - - - Few - - - - - - - - - -			
Rotifers	- - - - - - - Predominant - - - - - - -			

TABLE 60. MIXED LIQUOR MICROBIOLOGICAL INDICES AND FLOC CHARACTERISTICS - MARLBOROUGH SECOND STAGE - LAST COMPARTMENT

	PHASE 1	PHASE 2A	PHASE 2B	PHASE 3
Floc Characteristics				
Color	- - - - - - - Golden Brown - - - - - -			
Size	- - - - - Very Small to Small - - - - -			
Texture	Very Granular	Very Granular	Fairly Well Defined	Fairly Well Defined
Edges	- - - - - - - - - Jagged - - - - - - - - -			
Interspaces	- - - - - - - - - Clear - - - - - - - - - -			
Filamentous	Fairly Numerous	Numerous	Fairly Numerous	Fairly Numerous
Species				
Free Swimming Flagellates	- Few - - -	Few - - - -	Few - -	Fairly Numerous
Free Swimming Ciliates	- None - -	None - - -	Few - -	Few
Stalked Ciliates	- - - - - - - - - Few - - - - - - - - - - -			
Rotifers	- - - - - - - Predominant - - - - - - -			

in both compartments was the rotifers. No free swimming flagellates, and very few free swimming and stalked ciliates were observed.

Phase 2 - Results

Septage addition in Phase 2 did not adversely affect either floc or indicator organism population characteristics in the first stage process. Floc characteristics, including color, crispness of edges, and degree of turbidity in the interspaces, if anything, improved. Indicator organism populations remained stable and the occasional appearance of rotifers again indicated improved floc quality. No significant detectable changes in floc or indicator organism characteristics were observed in either nitrification stage compartment. A very slight increase in the free swimming flagellate population was not considered to be significant.

Phase 3 - Results

No significant changes in floc characteristics or indicator organism populations were observed in the first stage. Floc remained healthy in appearance and showed no signs of disruption or stress. One noticeable change observed in indicator organism characteristics was an increase in the size of the stalked ciliates.

No significant changes were detected in the floc characteristics observed during Phase 3 loadings in either nitrification compartment. A slight increase in free swimming flagellate concentration in both compartments was the only change observed in the indicator organism population and was not regarded as significant.

SECTION 10

ECONOMICS OF SEPTAGE TREATMENT

COST OF TREATING SEPTAGE AT MUNICIPAL PLANTS

Septage treatment costs for municipal wastewater treatment plants were divided into three categories: incremental operation and maintenance costs, capital costs for equipment and structures, and disposal site land costs. The emphasis of this cost analysis is the operation and maintenance costs associated with treatment at Medfield and Marlborough. These costs are applicable to similar processes and scales of treatment. A general discussion of capital costs is presented, but capital costs are site specific. Sludge disposal at land fills or by other means is not discussed, but must be included in septage treatment cost estimates. Land disposal is a significant and costly problem in some communities, while in other communities ample space is available for septage sludge disposal at a minimal cost.

OPERATING AND MAINTENANCE COSTS FOR TREATING SEPTAGE AT MEDFIELD

Records at the Medfield plant for the period prior to initiation of the research program indicated a fairly consistent addition of about 0.5%, by volume, of septage. This level of addition did not cause any modifications in plant operation, nor any disruption in performance. However, it was a substantial contribution to plant organic and solids loading and provided a baseline condition for estimating the cost of septage treatment. The baseline condition is shown in Table 61. Three separate methods were used to estimate operating and maintenance costs; each was based upon a separate set of assumptions.

Method 1 - Budget Item Cost Distribution

The operating budget of the plant was divided into thirteen accounts as shown on Table 62. Each of the accounts was apportioned between four characteristics of the wastewater: flow, organic loading, total solids, and phosphorus. Both BOD and COD were used as measures of wastewater organic content.

The cost distribution for Method 1 is shown on Tables 62 and 63. It was fairly easy to apportion power and chemical costs with reasonable accuracy, and these two budget items

TABLE 61. MEDFIELD TREATMENT PLANT AVERAGES AND YEARLY TOTALS

Parameter	Influent	Septage	Yearly Totals
Flow	1,135 cu m/day (0.30 mgd)	1,740 cu m/yr (460,000 gal/yr)	416,400 cu m (110×10^6 gal)
Organic Loading			
BOD	138 mg/l (156.6 kg/day)	4,664 mg/l (8,115 kg/yr)	65,300 kg/yr (144,000 lb/yr)
COD	293 mg/l (332.5 kg/day)	14,564 mg/l (25,340 kg/yr)	147,000 kg/yr (324,000 lb/yr)
Total Solids	437 mg/l (496 kg/day)	11,549 mg/l (20,100 kg/yr)	201,000 kg/yr (443,000 lb/yr)
Phosphorus	10.9 mg/l (12.4 kg/day)	127 mg/l (221 kg/yr)	4,740 kg/yr (10,440 lb/yr)

TABLE 62. PERCENT DISTRIBUTION - MEDFIELD - METHOD 1

	% Cost Based on Flow	% Cost Based on Organic Loading	% Cost Based on Total Solids Loading	% Cost Based on Phosphorus Loading
Electrical	36	21	42	1
Chemical	10		17.6	72.4
Supplies	30	30	30	10
Outside Services	33	33	33	1
Clean Sewer	100			
Travel	30	30	30	10
Uniforms	33	33	33	1
Telephone	30	30	30	10
Heat	15	15	65	5
Truck Fuel			100	
Motor Repair			100	
Consultant	10	20	60	10
Personnel	15	25	55	5

represent more than 40% of the total cost. The distribution of salaries, representing an additional 35% of overall costs, were based upon operator judgment. Some of the other ten budget items are specific to one characteristic of the wastewater, but

TABLE 63. COST DISTRIBUTION - MEDFIELD - METHOD 1

	TOTAL ANNUAL COST, $	FLOW $/cu m	ORGANIC $/kg BOD	$/kg COD	Solids $/kg SS	Phosphorus $/kg P
Electrical	21,306	0.0185	0.0685	0.0345	0.0445	0.0450
Chemical	23,686	0.0057			0.0207	3.6184
Supplies	7,000	0.0051	0.0322	0.0143	0.0105	0.1477
Outside Services	2,650	0.0021	0.0134	0.0060	0.0044	0.0056
Clean Sewer	1,000	0.0024				
Travel	250	0.0002	0.0011	0.0005	0.0004	0.0053
Uniforms	650	0.0005	0.0033	0.0015	0.0011	0.0014
Telephone	588	0.0004	0.0027	0.0012	0.0009	0.0124
Heat	8,100	0.0029	0.0186	0.0083	0.0262	0.0855
Truck Fuel	115				0.0006	
Motor Repair	300				0.0015	
Consultant	4,000	0.0010	0.0123	0.0054	0.0119	0.0844
Personnel	38,376	0.0139	0.1469	0.0653	0.1051	0.4049
TOTAL	108,021	0.0527	0.2990	0.1370	0.2278	4.4106
		$/1,000 gal	$/lb BOD	$/lb COD	$/lb SS	$/lb P
TOTAL		0.1995	0.1356	0.0621	0.1033	2.0003

most can only be distributed arbitrarily according to someone's most reasonable estimate, with due regard to floor space occupied, or in proportion to power consumed, etc. Justification is essentially subjective for these costs.

Unit costs of removal for each wastewater characteristic given on Table 63 were applied to average characteristics of septage. Values shown on Table 64 were computed in accordance with:

$$C = \Sigma(v + w \cdot BOD + y \cdot SS + z \cdot P)$$

or

$$C = \Sigma(v + x \cdot COD + y \cdot SS + z \cdot P)$$

where C = the cost of treatment per cu m (1,000 gal) of septage

BOD = the organic loading in kg/cu m (lb/1,000 gal) as biochemical oxygen demand

COD = the organic loading in kg/cu m (lb/1,000 gal) as chemical oxygen demand

SS = the suspended solids concentration in kg/cu m (lb/1,000 gal)

P = the phosphorus concentration in kg/cu m (lb/1,000 gal)

v = cost per cu m (1,000 gal) of liquid

w = cost per kg (lb) of BOD

x = cost per kg (lb) of COD

y = cost per kg (lb) of suspended solids

z = cost per kg (lb) of phosphorus.

Table 64 shows that the operation and maintenance cost of treating septage at Medfield was about $5.00 per cu m ($18.50 per 1,000 gal). This estimate is based upon an initial assumption that all functions and processes at a treatment facility are necessary and contribute to the treatment of septage, i.e., the cost of treating an increment of organics, for example, is the same for sewage and septage. Method 1 is considered extremely conservative and the costs shown overestimate septage treatment expenses.

A second method was employed in which a different initial assumption was made.

Method 2 - Limited Budget Cost Distribution

Fundamental to the second method is the assumption that many budget cost items are independent of septage addition. These items were not included in the septage treatment cost determination.

TABLE 64. BUDGET ITEM COST DISTRIBUTION - METHOD 1

Component	Strength mg/l	Strength kg/cu m (lb/1,000 gal)	Unit Treatment Cost	Component Cost, $/cu m ($/1,000 gal)
COD	14,564	14.6 (121.5)	$0.1370/kg ($0.0621/lb)	2.00 (7.55)
BOD	4,664	4.7 (38.9)	$0.2990/kg ($0.1356/lb)	1.41 (5.27)
SS	11,549	11.6 (96.3)	$0.2278/kg ($0.1033/lb)	2.64 (9.95)
P	127	0.13 (1.06)	$4.4106/kg ($2.0003/lb)	0.57 (2.12)
FLOW	--	--	$0.0527/cu m ($0.1995/1,000 gal)	0.05 (0.20)

TOTALS

Based on COD: (COD + SS + P + Flow) = $5.26/cu m ($19.82/1,000 gal)

Based on BOD: (BOD + SS + P + Flow) = $4.67/cu m ($17.14/1,000 gal)

Items included in the estimate were increased in various ways. Electrical costs were increased by whole machine units, i.e., power for an additional aerator, thickener or vacuum filter was put in service for septage treatment. Chemical costs were increased as flow, suspended solids, and phosphorus were increased. The personnel costs expanded incrementally by the addition of an additional staff member. Small increases in fuel and motor repair accounts were included for completeness.

This approach is somewhat dependent upon economics of scale. It is very unlikely that a large plant having many operators would experience anything approaching the 33% manpower increase called for in the Medfield case, where allowance for an additional full-time staff member was made on a three-man base. Some discrepancy might also be expected in the electrical budget if operational flexibility were allowed. This analysis did not allow variation in equipment use overtime; a rather extreme position in any circumstances. It is felt that the cost determined by this method is conservative for those items budgeted. The cost of treating septage, based upon the above assumptions, was $3.07/cu m ($11.62/1,000 gal). The results of the second analysis are shown in Table 65.

Method 3 - Incremented Effort Cost Evaluation

The results of the third cost analysis are also shown in Table 65. Base annual costs were actual costs incurred at

TABLE 65. PLANT COST COMPONENT DISTRIBUTION

	Base Annual Cost 0.5% Septage Condition	Incremented Item* Method 2 2% Septage Cost	Incremented Efforts** Method 3
Electrical†	$21,306	$22,802	$21,848
Chemicals	23,686	28,329	29,092
Truck Fuel	115	158	158
Motor Repair	300	413	413
Personnel††	38,376	51,168	45,929
Total	83,783	102,871	97,440
Incremental Cost		19,088	13,657
Cost/cu m (Cost/1,000 gal)		$3.07 ($11.62)	$2.04 ($7.72)

*Incremental volume of septage was 6,210 cu m/yr (1.64×10^6 gal/yr)

**Measured flow and septage volumes during testing were 908.4 cu m/day (0.24 mgd) and 18.35 cu m/day (4,848 gpd), respectively

†Electrical power costs were $0.0066/kw-h

††Personnel costs were computed on the basis of $49.20/man-day

Medfield. The same limited inventory of item cost categories was used as in Method 2. In Method 3 approximations were made of the change in effort induced by a 2% septage loading. These estimates were based upon the constant loading tests (Phase 2). There was no constraint to assume whole-unit increments of costs. The indicated treatment costs are therefore more independent of the economics of scale.

Based upon oxygen demand data, aerator output was increased four hours each day at the 2% loading. Labor costs were increased by four man-hours per day, based upon observation of the plant operation during the test period (Phase 2).

The cost of treating septage in Method 3 is based upon experience at Medfield during the test period, and represents a best estimate of actual incremental costs. The cost was $2.04/cu m ($7.72/1,000 gal).

Costs of treatment determined by each of the three sets of assumptions indicate clearly that treating septage along with domestic wastewater is a relatively expensive undertaking at an extended aeration facility. Septage treatment appears to cost about eight to twenty-two times as much as sewage treatment at Medfield.

Costs derived in Method 1 are clearly too high. Results for this method indicate that the cost of operating the Medfield plant at a 2% septage loading would increase the cost of operation by $30,567.00 per year, or by 28.3%.

The second and third methods, which address the costs in terms of increments of additional expenditure, clearly provide more realistic representations of the cost. Method 1 assumes a linear relationship between cost and waste characteristics. Only that part of the chemical costs for phosphorus removal closely approximates a linear model. Most other costs are essentially constant below a certain threshold (undefined), and then begin to respond in a way that has not been studied. Although Method 1 is not representative, it serves to indicate an upper limit.

Analyses 2 and 3 appear to show a reasonable range of costs. The cost would be larger at a small plant that might have a proportionally larger increment of cost due to putting on more staff, or because the machine time increment was large when processing septage at 2%.

A major portion of the cost of treating septage at Medfield is associated with oxidizing septage organics in the aeration basins. A conventional plant with primary clarification could expect to treat septage for less than experienced in an extended aeration mode of treatment.

MARLBOROUGH - ECONOMIC IMPACT OF SEPTAGE ADDITION

Septage additions at Marlborough were attenuated by the primary clarifier to such an extent that no significant increase in loadings were experienced by secondary or nitrification processes. As a result, increased operating expenses associated with accepting septage were reflected only in solids handling and disposal costs.

Items considered in ascribing costs to solids handling and disposal include: 1) chemicals, 2) vacuum filter manpower, 3) utilities, 4) vacuum filter maintenance - including filter cloth, 5) the solids disposal truck driver, and 6) the solids disposal site equipment operator. Capital equipment depreciation and disposal land costs are not included, thus, the following estimates are for additional operating costs only.

Estimates of present manpower requirements for the solids train,vacuum filter maintenance and cloth life were provided by the plant superintendant, as were the manpower requirements associated with the various elevated solids levels. Chemical costs were taken from present bid prices obtained at Marlborough. Cost projections have been made using the incremented effort method described in the Medfield study.

Table 66 shows unit costs and projected total solids treatment costs of 10, 50 and 100% over present levels for solids handling.

TABLE 66. SOLIDS HANDLING AND DISPOSAL UNIT COSTS AND ESTIMATED INCREASES AS A FUNCTION OF SOLIDS LOADING INCREASE - MARLBOROUGH

Item	Unit Cost	Usage Increase Increase in Solids Processed -%		
		10	50	100
Chemicals Lime	$0.0018/kg (7.85/ton)	10%	50%	100%
Ferric Chloride	$0.0497/kg (218.80/ton)	10%	50%	100%
Vacuum Filter Manpower	$7.05/man-hour	0	3 man-hrs / day	6 man-hours / day
Vacuum Filter Maintenance	$150/yr	10%	50%	100%
Vacuum Filter Cloth	$1800/yr	10%	50%	100%
Solids Disposal Truck Driver	$7.05/man-hour	0	1 man-hr / day	2 man-hours / day
Disposal Site Equipment Operator	$7.05/man-hour	0	6 man-hrs / week	12 man-hours / week
Utilities	$2755/yr (3% of total Utilities Budget)	0	20%	40%

Suspended solids data from Phases 2A and 2B indicate that a septage loading of 1.25% increased solids wasting by 54%, while a loading of 2.14% increased wastage by 100%. Therefore, the percentage increase in solids wasted is about 50 times the septage loading expressed as a percentage of flow. Since Marlborough presently accepts approximately 0.16% of its total flow as septage, increases in septage solids input of 10, 50 and 100% would correspond to total septage loadings of 0.36%, 1.16%, and 2.16%, respectively.

Total operating costs for solids handling and disposal at the various loadings are shown in Table 67. The relatively low cost of treating these levels of septage, when compared to the Medfield study, is a result of treating septage primarily in the solids train.

CAPITAL COSTS

Physical facilities for receiving, storing, feeding and treating septage are site specific. Capital costs from location to location can be expected to vary considerably.

An engineering design for a septage receiving station, located at a municipal treatment facility, would be based upon a number of considerations. These would include:

a. Anticipated septage loading, sewage flow rate and variability in septage hauling schedules
b. Is the receiving station to be constructed at an existing waste treatment plant or at a new plant?
c Are primary clarifiers available or planned for combined sewage and septage solids removal?
d. Is there capacity for septage treatment in secondary and tertiary processes?
e. Sludge dewatering procedures and operating schedules

A receiving station is required at all plants handling septage. Facilities exist that consist of nothing more than paving for truck egress and a discharge manhole leading to a grit chamber, a primary clarifier, or an aeration basin. This type of an arrangement is not nearly adequate. A receiving tank should be designed to permit feeding a plant septage at desired rates and on a schedule that is in harmony with solids wasting and dewatering operations. Holding facilities should be sized to permit septage flow attenuation and flexibility for plant operation and maintenance. Septage should be kept in suspension within a holding tank - air mixing is recommended. Mechanical grit removal equipment is necessary. Holding facilities and unloading areas should be covered and ozonation is suggested for odor control.

It is conceivable that septage holding tanks would be preceded by bar racks, but if screening devices are proposed,

TABLE 67. PRESENT AND PROJECTED COSTS OF SOLIDS HANDLING AND DISPOSAL - MARLBOROUGH

Item	Present Yearly Cost	10% Increase in Susp. Solids Handled	50% Increase in Susp. Solids Handled	100% Increase in Susp. Solids Handled
Chemicals	$16,650	18,315	24,975	33,300
V.F. Manpower	29,330	29,330	34,830	40,330
V.F. Cloth & Maintenance	1,950	2,145	2,925	3,900
Utilities	2,755	2,755	3,305	3,860
Disposal Truck Driver	14,670	14,670	16,500	18,340
Disposal Site Equipment Operator	5,870	5,870	8,070	10,270
Total	71,225	73,085	90,605	110,000
TSS Increase lb/year		174,700	873,400	1,746,800
Cost of Extra Solids $/metric ton ($/ton)		24.24 (21.99)	48.95 (44.40)	48.95 (44.40)
Cost of Treatment $/cu m ($/1000 gal) (at 11,000 mg/l TSS)		0.26 (1.00)	0.54 (2.04)	0.54 (2.04)

they must be chosen with considerable care, based upon documented experience with septage. Septage can be settled in a grit chamber, but unlike sewage grit, settled septage solids are highly organic and must be put through a dewatering and stabilization process. There are obviously any number of designs possible for receiving facilities and capital costs would vary accordingly. Capital costs for septage handling will also include the cost of large diameter mains and pumps to facilitate septage transmission without clogging.

Dewatering process costs can be the major capital expenditure associated with septage handling. An average capital cost estimate for total sludge handling for sewage sludge is about $132/cu m ($0.50/gal) of daily sewage flow.[19] Based upon a septage to sewage solids ratio of 50:1, the capital cost for total solids handling for sludge derived from septage is $6,600/cu m ($25,000/1,000 gal) of average daily septage input to a plant.

There would be a significant capital cost for aeration equipment for secondary treatment of septage with sewage. Since septage addition does not add appreciably to plant flow rate, final clarifier design can be based upon sewage loading. However, aeration tank size must be based upon the organic content of the combined sewage and septage influent to the secondary process. A considerable reduction can be made in aeration equipment and aeration tank size if a large portion of the incoming septage solids are removed in a grit chamber or primary clarifier.

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[19] Tihansky, Dennis P., "Historical Development of Water Pollution Control Cost Functions", Journal of Water Pollution Control Federation, Vol. 46, May 1974, pp. 813.

SECTION 11

SYNTHESIS OF RESULTS

DESIGN PARAMETERS

Septage Strength

Domestic septage is about fifty times as strong as domestic sewage. A 2% addition of septage, on the average, doubles solids and organic loading on the treatment facility. Septage is a readily treatable waste at extended aeration and conventional activated sludge plants. Mixed liquor bacteria are well adapted to assimilate septage; oxygen uptake rates increase rapidly as septage is added to an aeration basin. Septage does not exert an initial oxygen demand other than that caused by dilution of an anaerobic material in a partially aerated mixed liquor.

Domestic septage and sewage obviously derive from the same source, but in some respects, the properties of septage differ from those of sewage. Concentrations of solids, organics, and nutrients are obviously much higher; ratios of nitrogen and phosphorus to carbon tend to be lower than found in domestic sewage.

Chemical characteristics of septage are extremely variable and commercial and industrial wastes are, at times, hauled with domestic septage. Septage can contain grit, plastic material, and large amounts of hair that clog conduits and wear out equipment designed for handling sewage. Raw septage is difficult to dewater unless acidified, chemically treated with coagulants or mixed with raw or secondary sludge.

Design parameters for septage-sewage mixtures are given in the following sections.

Dissolved Oxygen Requirements

The aeration basins utilized for this study were fed septage in various ways, at a number of loading rates. The four aeration basins at Medfield were fed raw septage directly from holding tanks. The basins operated in series and mixed liquor solids concentrations were maintained at high levels.

First stage aeration basins at Marlborough were fed effluent from a primary clarifier receiving a combination of sewage and septage. The mixed liquor solids content of these basins was comparatively low, and the basins were operated in parallel. The nitrification stage (second stage) basins at Marlborough were not affected by septage addition. Non-oxidized remnants of septage added to the first stage were not found in secondary effluent.

The Lowell aeration basins were fed septage directly, while operating both as an extended aeration and conventional activated sludge facility.

The three plants were loaded both at constant rates and with pulse inputs. Lowell and Marlborough were loaded to near design capacity with sewage prior to septage addition. Medfield was very lightly loaded prior to septage addition, and had ample capacity for the large quantities of septage discharged directly to its aeration basins. Marlborough also received large quantities of septage, but at this plant the heavily loaded aeration facilities were protected by primary clarifiers that proved to be extremely effective in removing septage from the wastewater stream.

Dissolved oxygen utilization during the constant feed tests at Medfield was between 0.59 and 0.74 kg O_2/kg BOD_5. At Marlborough, utilization was between 0.69 and 1.11 kg O_2/kg BOD_5. Oxygen utilization based upon COD was more consistent at the two plants. averaging 0.21 kg O_2/kg COD at Medfield and 0.41 kg O_2/kg COD at Marlborough. At Lowell, oxygen utilization was 0.78 kg O_2/kg COD when the plant operated as a conventional process and 0.58 kg O_2/kg COD when it was operated in the extended aeration mode.

Oxygen utilization at treatment facilities depends upon mixed liquor solids concentrations, process loading, and, in general, plant operation. The above dissolved oxygen utilization estimates covered a wide range of operating conditions, and yet remained within the range of normal experience. Perhaps more germane, septage did not markedly change oxygen utilization rates experienced with sewage alone. The trend usually observed during the course of this research was an improvement (or decrease) in oxygen utilization per kg of COD or BOD, with septage addition.

The implication for designing constant-feed systems for septage is that oxygen demand can be estimated based upon parameters used for high strength sewage. Total oxygen utilization either for design or determining excess plant capacity, should be based upon average septage BOD, COD values, or, as an approximation, fifty times the value for sewage.

Assume, for example, that septage were added at a constant rate to a plant, doubling the organic loading, but not appreciably changing the hydraulic loading. Oxygen requirements based upon the equation,

$$O_2\left(\frac{kg}{day}\right) = \left[\begin{array}{c}\text{Food utilized}\\ \text{per day}\end{array} \quad - \quad 1.42\right]\left[\begin{array}{c}\text{organisms wasted}\\ \text{per day}\end{array}\right]$$

would approximately double. This, of course, assumes that wasting would be doubled to maintain a constant mixed liquor solids concentration, and that the BOD rate-constant is the same with or without septage. However, there is no reason to suppose that oxygen transfer efficiency will remain the same after septage addition. Increased food addition to a biological oxidation process generally lowers dissolved oxygen levels and improves transfer rates. Dissolved oxygen uptake rates increased significantly in Phase 2A at Medfield (2% constant septage feed for 3 weeks) and in the conventional mode tests at Lowell. Oxygen transfer at Medfield increased from 1.2 to 1.4 kg O_2/kw-h (2.0 to 2.3 lb/hp-h).

In conclusion, air requirements for activated sludge and extended aeration facilities can be based upon COD or BOD input to the secondary process and anticipated oxygen transfer efficiencies.

Shock loading can place a severe demand on a plant's aeration capacity. This was seen at Medfield and at Lowell. At Lowell, aeration capacity limitation finally upset the plant. At Marlborough the primary clarifier took the brunt of the septage input, diminishing the need for increased air capacity.

The initial oxygen demand caused by a shock load is the volumetric ratio of septage to mixed liquor, multiplied by the mixed liquor dissolved oxygen concentration. This demand is relatively minor. The major decline in dissolved oxygen (90% or more during this study) was caused by rapid increases in oxygen uptake rates. The general effects at Medfield were very low oxygen levels or a loss of mixed liquor dissolved oxygen for short periods of time. rapid recovery, and little or no effect upon effluent quality. However, if the quantity of septage is large enough, or if the loading is repeated too often, upset occurs as was experienced at the Lowell plant.

A plant can take at least twice as much septage if fed continuously than if shock loaded. This is based upon air requirements. If septage were not fed during periods of high sewage inflow, plant capacity would be further increased.

Sludge Production

The constant loading at Medfield provided a record of sludge wasting that enabled correlation between septage characteristics and cake production. There was, at Medfield, a direct relationship between total solids in combined sewage-septage influent and cake production. A 46% increase in total solids input in Phase 2A at Medfield resulted in a 41% increase in cake solids production. A 100% increase in BOD_5 and soluble COD at Medfield caused a corresponding 79% increase in production of mixed liquor volatile suspended solids.

Secondary sludge derived from a combination of sewage and septage at Medfield, or with primary sludge containing septage plus secondary sludge at Marlborough, did not affect vacuum filter performance. Chemical addition per unit weight of sludge did not vary and sludge cake characteristics remained unchanged.

The thickening process at Medfield changed perceptibly with increasing waste return sludge concentration--thickened sludge concentration declined. There was no change in the vacuum filter filtrate or in thickener supernatant.

Thickener and vacuum filter design for combined septage and sewage treatment can be based upon the solids and organic content of the combined plant influent, plant process characteristics, i.e., biological sludge production and the efficiency of primary clarification, and conventional thickener and vacuum filter design criteria.

Aeration Process Loading

Design parameters normally used for conventional and extended aeration plants appear to apply to plants receiving quantities of septage between 1 and 3% of the sewage flow. Typical values are shown in Table 68.

TABLE 68. TYPICAL DESIGN PARAMETERS*

	Conventional Activated Sludge	Extended Aeration
Mean Cell Residence Time, Θ_c, days	5-15	20-30
Food-to-microorganism Ratio, U, kg BOD_5/kg MLVSS-day	0.2-0.4	0.05-0.15
Mixed Liquor Suspended Solids, MLSS, mg/l	1,500-3,000	3,000-6,000
Volumetric Loading, kg BOD_5/cu m (lb BOD_5/1000, cu ft)	.32-.64 (20-40)	.16-.40 (10-25)

*Metcalf and Eddy, Wastewater Engineering, McGraw Hill, New York, 1972, p. 498.

Volumetric loading, kg BOD_5/cu m (lb BOD_5/1,000 cu ft) shown in Table 68 are considered conservative; while septage increases organic loading, it does not significantly increase hydraulic loading. Effluent quality is dependent upon mean cell residence time or the F/M ratio. Since the recycling rate is adjustable, treatment efficiency is theoretically independent of hydraulic retention. However, in practice, a minimum volume is required.

Primary Clarification

Primary clarifiers handling septage should be designed conservatively. Either surface loading or detention time criteria, customarily used for design, pertain to hydraulic loading and conventional values are based upon experience with domestic sewage.

Mixing of sewage and septage tends to diminish solids concentration differences at the inlet to a primary clarifier. Differences are greatly minimized if septage is fed at low constant rates instead of injecting slugs.

Septage solids appear to settle well in primary clarifiers. In the constant feed tests at Marlborough, 69% of the suspended solids load was removed from the wastewater stream by the primary clarifier. The heavy solids in septage appear to enhance settling. Density currents created by septage-ladened water did not upset clarification,but rather carried material more quickly to the clarifier bottom. This was observed during shock loading at Marlborough when 79.5 cu m (21,000 gal) of septage was input to the 1,318 cu m (345,000 gal) clarifier in a period of 30 minutes.

While septage does not appear to cause excessive short circuiting under constant septage feeding, accumulation of anaerobic solids at the bottom can cause upset. This has been a problem at Marlborough when sludge containing septage accumulated too rapidly or was not wasted quickly enough. particularly during summer months.

This research did not provide optimum design criteria for clarifiers treating septage and sewage. However, the Marlborough clarifier, loaded at design hydraulic capacity with sewage, functioned adequately while heavily loaded with septage.

The critical elements in clarifier design for combined sewage and septage solids removal are effluent quality, sludge removal and surface skimming. Settling and efficiency of removal appear to be enhanced by septage. Septage can add large quantities of grease solids which can quickly coat the surface of a clarifier. Particular attention should be paid to skimming mechanism design if septage addition is planned.

Removing settled solids rapidly requires not only adequate mechanisms but also adequate pump and dewatering capacity. Removal rate requirements can be quite high if septage is slug loaded or a plant accepts and treats many loads of septage on a particular day.

Secondary Clarification

Septage addition did not affect secondary clarification at either Medfield or Marlborough. Clarifier upset experienced at the University of Lowell plant was caused by oxygen deficiency at high septage loading. When mixed liquor samples were aerated during these high loading tests at Lowell, mixed liquor settled well in settlometers. Secondary clarifier design based upon conventional surface loading rates is recommended.

GUIDELINES FOR SEPTAGE ADDITION

Septage Handling and Receiving

Large quantities of septage are not easily handled at wastewater treatment plants, unless provisions are available or provided to accommodate the unique physical characteristics of septage. Septage can contain large quantities of grit, hair and stringy material. It is highly odoriferous and is a health hazard. The combination of these characteristics makes it a difficult material to handle, particularly at small plants where wastewater flows through small diameter conduits and pumps. Generally, pumps that pass grit without wear tend to clog with hair and string; grinder pumps that cut the hair obviously can't handle grit. The 15 cm (6 inch) centrifugal transfer pump used at Marlborough pumped about a thousand cubic meters (several hundred thousand gallons) of septage without clogging. The 8 to 10 cm (3 to 4 inch) submersible pumps, centrifugal pumps and plunger pumps used at Medfield clogged repeatedly. Fixed screens, with wire at 7 cm (3 inches) on center clogged readily with septage hair. Vibrating screens have been used successfully in experimental work.[20]

Handling the immense quantities of septage used in the course of this study left researchers with a very clear realization of the difficulties inherent in feeding septage at controlled rates. As a general rule screening is not recommended, and where feasible, gravity flow through large diameter pipes is preferred. If pumping is necessary, small quantities should be pumped intermittently at high rates with large pumps. Pumping once every 15 to 30 minutes is suggested.

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[20] A. J. Condren, "Pilot Scale Evaluations of Septage Treatment Alternatives", U. S. EPA, EPA-600/2-78-164, September 1978.

Septage is not sewage. Personal contact with septage while cleaning screens and unclogging pumps or pipes is highly undesirable. Designers cannot expect operators to perform tasks that are objectionable and hazardous. When septage handling at a plant is troublesome, haulers are turned away.

Continuous and Slug Loading

There are distinct advantages and disadvantages to both constant and shock loading septage at municipal plants. Constant loading places less of a demand on clarifier and aeration facilities. Septage can be fed during low sewage-flow periods, reducing the wide diurnal fluctuations of organic loading normally found at wastewater treatment plants.

Constant loading requires construction and maintenance of storage facilities and a septage transfer system that works at low flows. This is by no means a simple task. Gravity flow systems are best, but any flow control restriction easily plugs with septage. A well-engineered gravity system is most desirable and should be considered by design engineers. Intermittent pumping with large size pumps is feasible.

A number of treatment plants now use a modified constant flow system. Septage is discharged from trucks into an aerated grit chamber. Sewage is bled into the chamber, diluting and slowing displacing the septage. Each incoming septage load displaces an equal quantity of the diluted mixture. This type of system is better than direct discharge but obviously it can be improved upon.

Storage provides an opportunity to pretreat septage. Pretreatment might include grit removal, aeration, grease removal and chemical treatment of industrial loads of septage. Agitation and oxygen exchange normally provided in aerated grit chambers will neither keep all septage solids in suspension nor render septage aerobic. Aeration does drive off dissolved gases and will cause odor problems not experienced with quiescent holding tanks. Aeration also atomizes the septage liquid, putting potentially infectious bacteria and viruses into the air. Septage discharge, storage and pretreatment is best accomplished in closed tanks with proper ventilation and provision for odor control. Solids removal equipment should be designed for a suspended solids concentration of about 10,000 mg/l. Septage holding and feeding tanks must be provided with large capacity sludge removal equipment.

Operation Control Strategies

Control strategies differ, depending upon the size and type of plant accepting septage. The most cost effective way of handling septage is to move it to the dewatering stage with as little dilution as possible, i.e., wasting as much as possible from a primary clarifier or combining with primary and secondary sludge directly. This latter alternative has not been thoroughly investigated nor demonstrated at a plant, but research to date indicates that it is certainly worth considering. The approach does not require utilization of plant aeration capacity, which is often a limiting factor.

When aeration capacity or primary clarifiers are available, combining septage and sewage at a plant inlet has distinct practical advantages. Odor problems associated with storage of septage alone are avoided and transmission problems, e.g., clogging, are minimized.

Much can be accomplished in septage treatment by regulating hauling schedules and by feeding at times of relatively low process loading.

APPENDIX A

TABLE A-1

MEDFIELD TREATMENT PLANT PROCESS DIMENSIONS

Design Flow Rate: 0.066cu m/sec (1.5mgd)
Average Flow During Test Period: 0.012cu m/sec (0.28mgd)

Aerated Grit Chamber

Number of Units: 2
Number of Units in Use: 1
Length x Width x Height: 4.6m x 4.6m x 2.7m (15ft x 15ft x 9ft)
Volume: 56.8cu m (2005cu ft) (15000gals)
Detention Time During Test Period: 1.29hrs
Detention Time at Design Flow: 0.48hrs

Primary Sedimentation Basins

Number of Units: 2
Number of Units in Use: None (Used for Septage Storage)
Length x Width x Height: 25.3m x 4.6m c 2.7m (83ft x 15ft x 7ft)
Volume: 247cu m (8715cu ft) (65200gals)
Detention Time at Design Flow: 2.03hrs
Overflow Rate at Design Flow: 24.5cu m/sq m-day

Aeration Tanks

Number of Units: 2
Total Number of Compartments: 6
Number of Compartments in Use: 4
Compartment Length x Width x Depth: 9.1m x 9.1m x 3.7m (30ft x 30ft x 12ft)
Compartment Volume: 306cu m (10800cu ft) (80800gals)
Detention Time During Test Period: 7.08hrs
Detention Time at Design Flow: 1.29hrs

Final Clarifiers

Number of Units: 2
Number of Units in Use: 1
Diameter: 12.2m (40ft)
Depth: 2.7m (9ft)
Volume: 316cu m (11310cu ft) (84600gals)
Detention Time During Test Period: 7.25hrs
Detention Time at Design Flow: 2.71hrs
Overflow Rate During Test Period: 8.87cu m/sq m-day (219gpd/sq ft)
Overflow Rate at Design Flow: 24.4cu m/sq m-day (602gpd/sq ft)

TABLE A-2

MARLBOROUGH TREATMENT PLANT PROCESS DIMENSIONS

Design Flow Rate: 0.24cu m/sec (5.5mgd)

Average Flow During Test Period: 0.145cu m/sec (3.5mgd)

Aerated Grit Chamber

Number of Units: 2

Number of Units in Use: 1

Length x Width x Height: 7.6m x 3.7m x 2.5m (25ft x 12ft x 8.1ft)

Volume: 70.3cu m (2194cu ft) (16400gals)

Detention Time During Test Period: 0.12hrs

Detention Time at Design Flow: 0.14hrs

Storage Tanks (Old Aeration Tanks)

Number of Units: 2

Number of Units in Use: 0

Length x Width x Height: 18.3m x 3.7m x 2.4m (60ft x 12ft x 8ft)

Volume: 165cu m (5760cu ft) (99000gals)

Primary Settling Tanks

Number of Units: 2

Number of Units in Use: 1

Diameter: 21.3m (70ft)

Depth: 3.7m (12.2ft)

Volume: 1318cu m (47000cu ft) (352310gals)

Detention Time During Test Period: 2.56hrs

Detention Time of Design Flow: 1.54hrs

Overflow Rate During Test Period: 35.1cu m/sq m-day (857gpd/sq ft)

Overflow Rate at Design Flow: 29.1m/sq m-day (715gpd/sq ft)

Aeration Tanks 1st Stage

Number of Units: 2

Total Number of Compartments: 4

Number of Compartments in Use: 2

Compartment Length x Width x Height: 24.2m x 12.2m x 3.7m (80ft x 40ft x 12ft)

Compartment Volume: 1089cu m (38400cu ft) (287200gals)

Detention Time During Test Period: 4.18hrs

Detention Time at Design Flow: 5.01hrs

(continued)

TABLE A-2 (continued)

Secondary Clarifier

Number of Units:	2
Number of Units in Use:	1
Diameter:	27.4m (90ft)
Depth:	3.7m (12ft)
Volume:	288cu m(76200cu ft) (570000gals)
Detention Time During Test Period:	4.15hrs
Detention Time at Design Flow:	4.98hrs
Overflow Rate During Test Period:	21.1cu m/sq m-day (519gpd/sq ft)
Overflow Rate at Design Flow:	17.7cu m/sq m-day (432gpd/sq ft)

Aeration Tanks 2nd Stage

Number of Units:	2
Number of Units in Use:	1
Number of Compartments per Unit:	4
Unit Length x Width x Height:	24.4m x 24.4m x 3.7m (80ft x 80ft x 12ft)
Unit Volume:	2178cu m (76800cu ft) (574465gals)
Detention Time During Test Period:	4.2hrs
Detention Time at Design Flow:	5.0hrs

Nitrification Settling Tanks

Number of Units:	4
Number of Units in Use:	2
Diameter:	24.4m (80ft)
Depth:	3.7m (12ft)
Volume:	288cu m (76200cu ft) (570000gals)
Detention Time During Test Period:	4.15hrs
Detention Time at Design Flow:	5.04hrs
Overflow Rate During Test Period:	13.4cu m/sq m-day (328gpd/sq ft)
Overflow Rate at Design Flow:	11.1cu m/sq m-day (274gpd/sq ft)

TABLE A-3

UNIVERSITY OF LOWELL PILOT PLANT PROCESS DIMENSIONS

Flow Rate for Extended Aeration:	30.3cu m/day (1070cu ft/day) (8000gals/day)
Flow Rate for Conventional Process:	109.0cu m/day (3850cu ft/day) (28800gals/day)
Aeration Tank	
Number of Units:	1
Number of Sections:	2
Length of Each Section:	2.01m (6.6ft)
Width of Each Section:	2.74m (9.0ft)
Depth of Each Section:	2.74m (9.0ft)
Volume of Each Section:	15.1cu m (534.6cu ft) (4000gals)
Detention Time of Unit - Extended Aeration:	24.0hrs
Detention Time of Unit - Conventional Process:	6.7hrs
Settling Tank	
Number of Units:	1
Diameter:	2.73m (8.96ft)
Depth:	2.64m (8.67ft)
Volume:	15.45cu m (597cu ft) (4090gals)
Detention Time - Extended Aeration:	12.27hrs
Detention Time - Conventional Process:	3.41hrs
Overflow Rate - Extended Aeration:	5.17cu m/sq m-day (127gpd/sq ft)
Overflow Rate - Conventional Process:	18.6cu m/sq m-day (457gpd/sq ft)

APPENDIX B

TABLE B-1

MEDFIELD - PHASE I (no septage)

INFLUENT (mg/l)

Date	8/22	8/23	8/24	8/25	8/26	8/27	8/28	8/29	8/30	8/31	9/1	9/2	9/3	9/4	9/5*	9/6	9/7	9/8	9/9	9/10	9/11	9/12	x̄
Day	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	
Flow Rate, mgd	.227	.203	.276	.238	.232	.200	.165	.199	.226	.209	.192	.198	.157	.129	.129	.189	.195	.242	.340	.203	.180	.205	.206
COD-Total	232	254	373	247	266	286	119	273	174	390	202	362	319	240	361	395	289	296	117	283	259	340	276
COD-Soluble	83	87	103	87.6	75.4	75.4	43.7	115	79.1	108	91.3	80.7	66.9	66.9	95.2	115	111	111	36.4	85.0	72.9	134	
BOD-Total	130	110	170	139								144	127	107	168	170	133	150					141
BOD-N Suppressed	71	95	94	81	69	69	39	70	68	133	89	107	103	98	134	127	101	114	95	74	88	117	92.5
Total Organic Carbon	80	78	89		63	74		62		93	68	78	69	66	90	73		67					
Total Solids	479	432	458	400	408	424	339	427	366	422	401	532	447	429	546	496	408	483	465	391	421	630	446
Total Volatile Solids	166	222	173	156	166	188	112	183	184	175	137	234	178	146	297	231	170	191	180	141	162	266	184.5
Suspended Solids	64	67	184	82	61	94	37	48	18	204	46	178	146	141	211	165	104	115	141	62	100	119	108
Volatile Susp. Solids	64	26	172	67	44	82	18	39	9	148	33	148	110	106	159	142	84	93	105	51	75	92	
Total Kjeldahl-N	22.9		25.5					27.4		21.6					30.8		25.2					29.1	26
Ammonia-N	13.9	12.1	11.2	13.1	13.4	11.5	9.4	12.4	12.5	12.3	13.7	13.2	10.3	13.6	14.2	13.4	13.3	15.4	14.5	15.0	14.3	16.8	13.2
Nitrate-N	.02	.01	.025	.01	.03	.035	.06	.04	.04	.07	.04	.07	.07	.07	.04	.02	.02	.01	.11	.03	.02	0	
Total Phosphorus	7.7		17.5					5.8		10.5					11.5		10.0					11.0	
Grease		126							24.8														
pH		7.2	7.3	7.2	7.3	7.0	7.0	7.1	7.3	6.7	7.0	6.8	7.1	7.1	7.1	7.1	7.0	7.1	7.0	7.2	7.1	7.2	
Temperature, °C		17	17	17	17	17	17	18	18	18	17	19	18	18	18	18	17	18	17	21	19	17	
Alkalinity, $CaCO_3$	138	140	133	140	125	133	99	137	130	142	141			138	144	136	132	145			147	155	

*Labor Day

TABLE B-2

MEDFIELD - PHASE I (no septage)

SECONDARY EFFLUENT (mg/1)

Date	8/23	8/24	8/25	8/26	8/27	8/28	8/29	8/30	8/31	9/1	9/2	9/3	9/4	9/5	9/6	9/7*	9/7‡	9/8	9/9	9/10	9/11	9/12	x̄
Day	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Wed	Thur	Fri	Sat	Sun	Mon	
COD-Total	16	19.8	23.8	27.9	23.8	27.8	15.9	23.7	19.8	23.9	15.9	15.8	15.8	19.7	23.8	19.8	27.7	15.8	16.2	8.1	4.0	23.7	19.5
COD-Soluble	16	15.9	27.8	19.9	23.8	23.8	19.8	19.8	15.8	23.9	11.9	11.8	15.8	7.9	19.8	15.8	23.7	15.8	16.2	12.1	4.0	23.7	17.5
BOD-Total	7.8	6.6	5.5	3.9								1.6	2.1	1.6	2.3	2.5		2.2					3.6
BOD-N Suppressed		2.4	1.5	0.9	1.1	0.8	1.2	1.1	0.6	0.4	0.6	1.0	0.6	0.8	0.3	0.5		0.4	2.7	1.2	1.1	0.7	1.0
Total Organic Carbon	6.6	6.6	4	6.5	6	6	23	13.5		4.5	5	5	3	25	8	72		10.5	14.5				12.9
Total Solids	372	312	287	327	312	311	345	347	318	320	355	343	309	330	397	316	308	368	339	334	346	378	336
Total Volatile Solids	62		55	90	70	75	120	92	138	86	97	51	41	38	100	69	77	110	63	78	57	75	78.3
Suspended Solids	4.4	3.4	6.6	4.8	4.3	3.2	5.4	3.8	1.7	4.3	8.0	5.2	5.0	4.5	4.3	4.2	0.6	4.5	5.3	1.6	0.6	1.8	4.0
Volatile Susp. Solids	3.8	1.4	3.9	4.3	2.6	2.0	3.7	2.8	1.7	2.1	6.7	3.9	3.3	3.4	2.8	3.9	0.6	3.3	4.2	1.1	0	1.1	2.85
Ammonia-N	0	.56	.54	.39	.11	.06	0	.17	.65	.28	.11	.11	.22	.11	.19	.06	0	.01	.17	.11	0	.22	.18
Nitrate-N	0.8	.22	.21	1.73	2.2	1.86	2.6	1.3	3.8	6.75	7.85	6.0	5.9	7.4	8.2	7.2	7.0	6.8	7.5	7.6	7.75	7.72	4.93
Total Phosphorus	.61		.41					.77		.68					.74		.68					.78	.67
Grease		5.0							4.0														
pH	7.5	7.4	7.3	7.1	7.4	7.0	7.2	7.3	7.3	7.1	7.4	7.2	7.3	7.2	7.3	7.3		7.2	7.4	7.5	7.4	7.4	
Temperature, °C	19	19	19	18	19	19.5	21	21	20	20	21	22	20	19	19	21		19	17	19	18	16	
Sodium Aluminate, gal	15.4	15.4		17.6	17.6	13.2	17.6	17.6	8.8		19.8	17.6	13.2	13.2	17.6			15.4	15.4	17.6	13.2	13.2	

* Grab samples taken 8/23 through 9/7

‡ Composite samples taken 9/7 through 9/12

TABLE B-3
MEDFIELD - PHASE I (no septage)
MIXED LIQUOR (mg/l)

Date	8/23	8/24	8/25	8/26	8/27	8/28	8/29	8/30	8/31	9/1	9/2	9/3	9/4	9/5	9/6	9/7	9/8	9/9	9/10	9/11	9/12
Day	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon
Total Solids	9140		7880	8320	8680	8130	8320	8770	7760	8100	8010	7880	7930	8100	8520	7680	7990	7890	7520	7700	7790
Total Volatile Solids	6820		4730	5050	5290	4850	5080	5300	4610	4810	4810	4620	4540	4580	5110	4480	4690	4590	4400	4990	4530
Suspended Solids	8490	8620	7710	8010	8410						7850	7540	7590	7740	8160	7350	7680	7540	7180	7340	7450
Volatile Susp. Solids	5260	5890	5190	5020	5080						4620	4530	4450	4490	5000	4390	4610	4500	4320	4940	4480
pH	7.1	7.2	7.1	7.0	6.9	7.0	7.2	7.0	7.0	7.0	6.9	6.9	7.0	7.1	7.0	7.1	6.8	6.9	6.9	6.9	6.8
Temperature, °C	20	19	19	18	19	20	21	21	20	20	21	22	20	19	19	20	19	18	19	19	17
Alkalinity, $CaCO_3$	246	245	229	223	284	306	283	255	223	242	244			233	245	257	221	164			192
D.O. Uptake, mg/l/hr	12.6	18.3	6.9	24.0	9.3	14.7	14.9	27.0	17.6	11.2	16.4	16.8	15.1	10.1	12.3	15.0	9.2	26.7	12.6	13.5	10.6
Dissolved Oxygen																					
Basin #1	5.9	2.1	4.0	3.9	4.3	4.9	4.2	3.5	4.0	4.1	4.1	3.2	4.9	4.3	6.2	5.6	4.7	6.3	5.7	5.9	6.65
#2	.65	.45	.8	1.3	1.6	.5	.5	.8	1.25	1.2	0.8	0.8	0.9	1.3	1.8	0.6	0.5	2.4	1.9	1.7	2.6
#3	.75	.70	1.0	1.0	1.6	.3	.4	.8	1.20	1.0	0.5	0.5	0.6	1.05	1.75	0.25	0.1	2.1	1.1	1.2	2.5
#4	1.1	1.10	.8	.9	1.5	.2	.5	.7	1.10	1.0	0.4	0.5	0.6	1.0	1.75	0.3	0.2	2.05	1.0	1.1	2.3
Clarifier	1.2	1.6	1.0	1.2	1.5	.3	.4	.9	1.20	1.25	0.6	0.7	1.2	1.25	2.1	0.4	0.1	2.0	1.2	1.1	2.3
Settlometer																					
5 minutes	980	920	960	960	950	950	950	950	950	890	950	950	950	960	950	970	955	960	950	920	950
10 minutes	950	850	920	910	900	900	900	900	870	790	900	900	905	910	900	910	900	900	880	830	900
15 minutes	920	790	870	870	870	860	860	870	800	700	840	840	850	870	860	860	840	850	830	730	840
20 minutes	890	730	830	830	830	815	815	830	730	630	790	780	810	820	820	800	780	790	770	660	780
25 minutes	860	670	790	790	800	770	770	790	670	570	740	720	760	775	780	750	740	740	700	590	720
30 minutes	830	620	750	750	760	735	740	760	620	530	690	670	720	730	735	700	680	690	660	550	670
45 minutes	750	510	640	640	650		640	650	510	450	580	560	610	610	630	575	560	570		460	560
60 minutes	670	450	560	560	610		560	570	460	400	510	490	530	540	550	500	490	500			490

TABLE B-4
MEDFIELD - PHASE I
SECONDARY RETURN SLUDGE (mg/1)

Date	8/23	8/24	8/25	8/26	8/27	8/28	8/29	8/30	8/31	9/1	9/2	9/3	9/4	9/5	9/6	9/7	9/8	9/9	9/10	9/11	9/12
Day	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon
Total Solids	11720	8560	6070	10410	7400	10390	5980	8080	9280	11860	14910	10630	11040	9550	9860	10970	9900	9330	10430	10320	9820
TVS	6940	5330	3540	6310	4510	6300	3590	4860	5590	7020	9410	6230	6330	5400	5750	6510	5860	5440	6135	6000	5720
Settlometer																					
5 minutes										970					970		970				
10 minutes										920					940		945				
15 minutes										870					910		920				
20 minutes										840					870		890				
25 minutes										790					850		870				
30 minutes										750					820		840				
45 minutes										650					740		765				
60 minutes										570					675		700				
Flow Rate, mgd	.427	.430	.407	.453	.417	.374	.428	.431	.403	.411	.453	.430	.427	.374	.433	.441	.429	.469	.418	.370	.421
Capillary Suction Test										9.7					9.1		8.5				

TABLE B-5
MEDFIELD - PHASE I (no septage)

THICKENER AND VACUUM FILTER(mg/l except Sludge and Cake Values)

	THICKENER						VACUUM FILTER					
	Supernatant			Sludge			Filtrate			Cake		
Date	8/30	9/6	9/15	8/30	9/6	9/15	8/31	9/9	9/15	8/31	9/9	9/15
COD-Total	27.7	27.7	20.0				328	257	488			
BOD-Total	7	1.8					120					
BOD-N Suppressed		0.7					101		222			
Total Organic Carbon	15	10					77	104				
Total Solids	332	307	347	5.83%	5.26	5.62	640	856	809	12.69%	11.35	12.62
Total Volatile Solids	82	72	58	3.57	3.15	3.35	284	438	421	7.73	6.82	7.60
Total Susp. Solids	3.3	0	0				55	89	106			
Total Vol. Susp. Solids	3.3	0	0				34	61	70			
Capillary Suction Test				15.75	20.95	10.5						
Volume, gal	40430*	39570*	31350*	6770*	8230*	7660*						
Conditioned Sludge Capillary Suction Test							15.5	10.9	9.8			

*Total Supernatant and Sludge

TABLE B-6
MEDFIELD - PHASE I (no septage)

MICROBIOLOGICAL INDICES (mg/l)

Date	8/25	8/26	8/29	8/30	8/31	9/1	9/2	9/5	9/6	9/7	9/8	9/9	9/12	9/13
Mixed Liquor														
Total No. Organisms (N)	73	144	83	65	77	44	48	78	29	29	25	70	166	171
Total No. Species (S)	4	7	7	9	7	7	8	7	9	8	4	6	7	7
Diversity Index ($\bar{H}$)	.95	1.47	2.15	2.18	2.12	2.33	1.93	1.84	2.79	1.94	1.15	1.76	1.64	1.48
No. Organisms														
Vorticella	11	39	28	18	28	14	17	8	7	-	1	-	25	12
Colpoda & Euplotes	58	91	27	20	27	14	22	48	8	18	19	44	110	122
Micro Flagellates		1	16	20	1	4	1	9	1	1		6	4	1
Macro Flagellates	3	3	1	2	7	5	1	3	1	1			1	2
Rotifers	1	2	7	1	4	1	4	7	3	1		4	7	7
Diatoms		4	2	1	1	1	1	1						
Lionotes				1			1	2	1	3	2	9	10	8
Micro Ciliates			2	1	9	5	1		1	1				
Suctorians				1					3	1	3	2		
Nematodes														
Spirochetes		4							1	3		5	9	19
Effluent														
Total No. Organisms (N)						30			22		15			10
Total No. Species (S)						6			6		5			7
Diversity Index ($\bar{H}$)						1.67			2.05		2.11			2.72
No. Organisms														
Ciliates						5			7					1
Green Filaments											6			1
Micro Flagellates						3			3		3			
Macro Flagellates									1		2			2
Scenedesmus						1			1					1
Colpoda						1			1					
Pennates						19			9		3			2
Naviculum														
Rotifers														
Paramecium											1			
Nematodes														
Vorticella						1								

(continued)

TABLE B-6 (continued)

Date	8/25	8/26	8/29	8/30	8/31	9/1	9/2	9/5	9/6	9/7	9/8	9/9	9/12	9/13
Return Sludge														
Total No. Organisms (N)	92	114	93	98	76	64	45	59	29	54	71	90	142	156
Total No. Species (S)	6	6	6	5	7	7	6	4	7	8	11	8	7	6
Diversity Index ($\bar{H}$)	.88	1.01	1.92	1.92	2.25	2.23	1.84	1.51	1.68	1.95	2.36	2.42	1.33	1.42
No. Organisms														
Vorticella	5	14	11	33	18	21	7	15	1		21	18	1	11
Colpoda & Euplotes	82	92	37	41	33	24	27	33	19	33	30	53	107	113
Micro Flagellates			34	10	3	5	2			2	1	4	4	
Macro Flagellates	2	4	8	10	7	2	3		1	5	3			1
Rotifers	1	1	2	4	5	4	3	10	1	5	5	3	6	7
Diatoms	4	2			2				1	2	1			
Lionotes						2		1	5	5	5	6	14	10
Micro Ciliates	1	1	1		8	6	3			1	2			
Suctorians									1	1	1	2		
Nematodes											1		1	
Spirochetes											1	4	9	14

APPENDIX C

TABLE C-1

MEDFIELD - PHASE IIA (continuous loading)

SEPTAGE (mg/l)

Date	9/13	9/14	9/15	9/16	9/17	9/18	9/19	9/20	9/21	9/22	9/23	9/24	9/25	9/26	9/27	9/28	9/29	9/30	10/1	10/2	10/3
Day	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon
COD-Total	8730	5200	3080	4580	4680	2780	4620	3560	8480	30000	11110	11030	34600	14560	6960	9200	7550	58180	24800	9170	14120
COD-Soluble		1120												1520	880	1360	880	2130	1417	1260	5180
BOD-Total	2350								9300	12200	2190	2670		1620	1500	2130	3810	10000	3810	1845	
BOD-N Suppressed	1500	2250	2320	2325	3970	2820	810		9600	10100	2790	2610			1280	1710	1640	10000	3450	1180	1980
Total Solids	6210	3140	2500	2620	2980	2510	3150	2770	5230	5980	6010	5780	13650	8830	4750	4450	5450	12260	13530	7560	8930
Total Volatile Solids	4750	2300	1670	1780	1920	1700	2170	1910	3650	4200	4240	4130	8890	5570	2920	2650	3600	6280	10230	5600	6710
Suspended Solids	5530	2450	1490	1310	1900	1650	1950	1750	3310	4050	5130	3750	10340	6690	3010	2810	3930	10620	11400	5850	7330
Volatile Susp. Solids	4440	2000	1190	1080	620	1320	1610	1290	2800	3550	3540	3110	7000	4860	2250	2060	2980	5620	9160	4650	5920
Total Kjeldahl-N		174		153	146		165		208		304		213	246		183					340
Ammonia-N	50.4	37.3	22.4	79.5	74.2	56.0	73.9	58.2	73.9	69.4	94.1	77.3	109	86.2	72.8	81.8	70.6	115	72.8	91.8	60.5
Total Phosphorus	220	60		200			110		105		120	120	160	120	105	95	120	215	87	70	
Grease	590		6320					5940		6260					6500		400				
pH	6.9	6.9	7.1	7.1	7.1	7.1	7.1	7.3	6.5	6.9	6.8	6.6	8.1	7.3	7.2	6.7	6.7	6.0	6.3	6.4	6.8
Temperature, °C	20	17	22	18	23	21	19	16	16	18	14	16	18	18	18	18	15	18	19	18	16
ORP	-710	-800	-785	-780	-540	-780	-585	-750	-580	-830			-580	-680	-560	-750	-570	-610	-680		
Volume, gal	4030	5970	5340	4700	3910	4220	5320	5220	4210	4780	4900	4300	4670	4870	5050	4840	4770	4220	4340	3860	4630
% of Daily Flow	2.13	2.61	2.68	2.03	2.08	2.37	2.44	2.04	1.85	2.17	2.14	1.94	2.27	1.50	1.90	1.88	1.90	1.69	1.62	1.51	1.60
Alkalinity						303	400	364	450	426			1149	745	631	599	439	495	490	335	381

TABLE C-2

MEDFIELD - PHASE IIA (continuous loading)

INFLUENT (mg/1)

Date	9/13	9/14	9/15	9/16	9/17	9/18	9/19	9/20	9/21	9/22	9.23	9.24	9.25	9.26	9.27	9.28	9.29	9.30	10.1	10.2	10.3	10.4	x̄
Day	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	
Flow Rate, mgd	.189	.229	.199	.232	.188	.178	.218	.256	.228	.220	.229	.221	.206	.324	.266	.257	.251	.261	.268	.256	.290		.236
COD-Total	298	328	312	672	198	230	327	395	372	272	413	409	222	456	204	296	257	249	189	197	172		308
COD-Soluble	119	100	148	198	77.4	87	48	154	180	116	270	155	95	100	72	84	76	83	83	150	82		
BOD-Total									141	158		237	99	208	72	147	176						114
BOD-N Suppressed	119	126	123		52	87	72	194	128	122		178	117	154	88	107	119	111	103	77	105		
Total Organic Carbon	76	79	69				66		76	65			56	78									
Total Solids	461	457	414	697	368	379	488	450	444	446	482	507	438	496	377	460	443	483	341	347	425		
Total Volatile Solids	176	178	145	410	120	126	244	196	165	164	217	259	182	235	115	159	193	205	135	179	174		
Suspended Solids	74	110	64	353	37	59	253	159	100	66	120	141	63	209	70	112	86	109	30	67	121		
Volatile Susp. Solids	68	92	48	259	35	52	186	99	74	66	89	107	44	124	59	83		82	25	59	99		
Total Kjeldahl-N		27.2		36.1	24.9		23.8		24.9		27.2		22.1	23.0		23.0					24.6		
Ammonia-N	19.1	17.0	17.8	17.8	16.3	14.3	11.4	13.9	15.3	17.4	18.0	14.7	13.4	12.0	13.2	14.1	15.1	15.7	10.9	10.2	14.1		14.8
Nitrate-N	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
Total Phosphorus		9.2	7.2	16.5			13.0		9.8		11.0	11.0	11.5	10.7	10.7	16.2	11.5	12.5	9.0	8.5			
Grease		79.2							83.2						20								
pH	7.3	7.2	7.0	7.2	7.1	7.1	6.8	7.2	7.1	7.3	7.1	6.8	6.7	7.4	7.5	7.0	7.1	6.7	6.7	6.6	7.0	7.0	
Temperature, °C	17	17	17	18	17	19	18	17	15	16	17	16	14	17	17	17	17	16	16	16	18	15	
Alkalinity	166	153	150	160		145	118	129	145	159			143	126	143	158	157	153	129	122	148		

TABLE C-3

MEDFIELD - PHASE IIA (continuous loading)

SECONDARY EFFLUENT (mg/l)

Date	9/13	9/14	9/15	9/16	9/17	9/18	9/19	9/20	9/21	9/22	9/23	9/24	9/25	9/26	9/27	9/28	9/29	9/30	10/1	10/2	10/3	10/4	$\bar{x}$
Day	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	
COD-Total	11.9	20.0	12.0	24.0	43.8	24.0	19.9	19.8	32.0	24.0	135.	67.5	43.7	32.0	32.0	24.0	36.1	19.8	19.7	55.1	35.3		34.3
COD-Soluble	11.9	20.0	16.0	24.0	13.8	15.8	19.9	19.8	16.0	24.0	35.7	27.8	39.7	28.0	24.0	12.0	24.1	15.8	11.8	35.4	35.3		22.4
BOD-Total									1.9	1.8	3.2	4.1	2.4	2.8	8.6	2.4	2.8	1.1	8.2	5.4	2.4		3.6
BOD-N Suppressed	0.5	1.9	1.8		0.3	0.6	0.2	0.7	0.9	0.4	1.8	0.9	0.7	0.4	3.0	0.2	1.4	0.5	3.2	1.4	0.4		1.2
Total Organic Carbon	4.5	5	6.5			5		3	5	16.5	7.5	6	5.5	5									5.9
Total Solids	353	332	349	326	292	280	293	269	308	339	330	351	378	306	332	341	344	355	270	309	465		330
Total Volatile Solids	72	45	98	121	34	39	56	47	65	60	68	83	96	69	79	72	72	68	60	100	65		70
Suspended Solids	0.9	2.8	2.8	2.4	0.8	1.5	3.3	3.7	3.3	1.5	2.7	3.1	1.8	2.7	8.6	2.0	8.0	0.4	0.4	3.4	9.2		3.1
Volatile Susp. Solids	0.4	2.5	1.6	2.2	0.6	1.1	2.0	2.6	2.2	1.5	1.5	1.6	0.8	0.8	6.7	1.3	0	0.2	0.2	3.2	6.9		1.9
Ammonia-N	.06	.62	.30	1.8	5.4	5.2	5.2	6.1	5.6	3.5	5.0	4.5	2.1	2.2	3.5	2.3	1.4	1.3	0.7	1.1	2.2		2.9
Nitrate-N	9.0	8.4	12.5	6.5	4.6	6.1	6.5	5.6	2.3	1.7	2.5	2.7	1.6	1.5	0.2	0.6	2.2	4.0	1.3	0.8	0.8		3.9
Total Phosphorus	1.2	1.1	2.1	2.1		2.0	2.1	2.3	2.4		2.4	1.9	1.6	1.8	0.9	0.3	0.6	0.6	0.8	0.7	0.8		1.5
Grease		4.4							4.0						3.2								
pH	7.3	7.2	7.1	7.3	7.2	7.2	7.3	7.3	6.8	6.8	7.2	7.5	6.7	7.3	7.6	7.0	7.5	6.9	6.9	6.3	6.6	6.9	
Temperature, °C	18	18	18	18	18	21	19	19	15	16	16	15	13	18	18	18	17	16	18	18	18	16	
$Na_2O \cdot Al_2O_3$, gal	15.4		39.6	←13.2→				8.8	11.0	6.6	8.8	8.8	8.8	15.4	17.6	26.4		22.0	19.8	19.8	17.6	19.8	

TABLE C-4

MEDFIELD - PHASE IIA

MIXED LIQUOR (mg/1)

Date	9/13	9/14	9/15	9/16	9/17	9/18	9/19	9/20	9/21	9/22	9/23	9/24	9/25	9/26	9/27	9/28	9/29	9/30	10/1	10/2	10/3	10/4
Day	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri*	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues
Total Solids	8160	8160	7760	7880	7750	7840	7590	8150	8330	7570	5700	8200	7910	8650	8300	7250	7770	8020	8080	8500	8530	8600
Total Volatile Solids	4740	4790	4490	4630	4630	4520	4340	4810	4880	4490	3300	4890	4750	5180	4890	4280	4640	4760	4700	5000	5080	5200
Suspended Solids	7750	7830	7460	7550	7420	7540	7360	7870	8060	7260	5350	7860	7530	8250	8000	6930	7420	7680	7770	8010	8210	8300
Volatile Susp. Solids	4640	4710	4450	4570	4550	4450	4310	4790	4850	4400	3260	4800	4640	5100	4870	4250	4560	4630	4590	4890	4960	5140
pH	6.9	7.3	6.3	6.9	7.1	7.2	7.0	7.1	7.0	6.5	7.0	7.1	6.8	6.8	7.4	7.0	6.9	6.7	6.8	6.7	6.5	6.9
Temperature, °C	17.5	18.5	18	18	18	22	19	18	16	17	18	14	15	17	19	18	17	16	18	19	17	16
Alkalinity	205	188	200	250	244		252	235	216	220	186			209	224	280	266	268	256	272	268	283
D. O. Uptake, mg/1/hr	10.4	12.9	17.1	11.8	16.8	23.3	20.4	20.9	18.9	15.7	14.5	23.0	22.6	20.2	27.4	25.7	21.4	23.3	28.6	28.2	33.2	17.3
Dissolved Oxygen																						
Basin #1	6.0	2.8	4.3	4.8	5.05	4.45	2.9	3.4	3.6	3.8	7.8	2.5	2.8	3.8	2.4	2.4	1.5	4.0	2.7	2.4	3.4	4.2
Basin #2	1.9	1.05	0.9	0.7	0.7	0.45	0.6	0.4	0.4	0.4	0.8	0.2	0.3	0.5	0.8	0.2	0.2	0.4	0.3	0.4	0.3	0.2
Basin #3	1.7	0.8	0.6	0.6	0.7	0.40	0.5	0.4	0.3	0.45	0.7	0.2	0.2	0.45	0.9	0.2	0.2	0.4	0.3	0.2	0.3	0.2
Basin #4	1.9	0.7	0.6	0.45	0.6	0.40	0.5	0.35	0.3	0.4	0.65	0.1	0.2	0.45	0.9	0.2	0.2	0.3	0.3	0.4	0.2	0.3
Clarifier	1.8	0.8	0.7	0.3	0.65	0.35	0.4	0.3	0.5	0.5	0.8	0.2	0.2	0.55	1.1	0.4	0.3	0.4	0.5	0.5	0.4	0.2
Settlometer																						
5 minutes	950	950	960	960	960	940	960	950	965	950	800	920	940	980	950	940	960	960	960	950	960	955
10 minutes	900	900	910	910	910	880	910	900	930	900	620	850	910	940	900	890	900	915	910	900	920	915
15 minutes	850	840	860	860	830	830	860	850	880	850	510	780	870	900	855	845	850	860	860	860	880	860
20 minutes	850	790	810	810	810	775	810	800	830	805	450	720	830	860	810	800	800	810	815	800	840	815
25 minutes	750	735	760	760	725	760	750	790	760	410	410	660	790	820	770	755	750	760	770	740	800	765
30 minutes	690	680	700	710	710	675	715	710	740	710	380	620	750	780	730	710	690	710	725	680	760	720
45 minutes	500	560	580	590	580	560	600	600	610	590	340	520	640	690	620	600	585	600	610	560	640	600
60 minutes	460	490	490	510	500	490	510	520	530	500	325	470	550	590	540	510	500	510	525	500	510	520

*Sludge return off, 3pm to 8am

TABLE C-5

MEDFIELD - PHASE IIA (continuous loading)

SECONDARY RETURN SLUDGE (mg/l)

Date	9/13	9/14	9/15	9/16	9/17	9/18	9/19	9/20	9/21	9/22	9/23	9/24	9/25	9/26
Day	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon
Total Solids	9700	10070	9910	9770	10000	10060	12130	10610	10740	9760	35060	9120	9190	11030
TVS	5630	5840	5760	5650	5900	5830	6970	5310	6290	5770	20750	5430	5550	6570
Settlometer														
5 minutes	960		980					980		970				
10 minutes	930		960					960		945				
15 minutes	900		935					940		920				
20 minutes	870		910					915		890				
25 minutes	840		880					895		865				
30 minutes	790		830					870		840				
45 minutes	630		770					810		710				
60 minutes	580		690					750		690				
Flow Rate, mgd	.421	.438	.448	.417	.450	.348	.403	.399	.395	.128*	.413	.374	.359	.382
Capillary Suction Test	9.25		8.75				9.1		8.5					10.5

Date	9/27	9/28	9/29	9/30	10/1	10/2	10/3	10/4
Day	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues
Total Solids	12020	8250	10930	10380	11050	11720	11550	11490
TVS	7090	4860	6560	5750	6360	6930	6890	6950
Settlometer								
5 minutes	990		970					
10 minutes	970		940					
15 minutes	955		915					
20 minutes	940		890					
25 minutes	920		870					
30 minutes	900		840					
45 minutes	855		770					
60 minutes	800		690					
Flow Rate, mgd	.433	.392	.420	.419	.493	.400	.433	
Capillary Suction Test		10.9						10.1

*Return sludge pump off from 2pm to 7am

TABLE C-6

MEDFIELD - PHASE IIA (continuous loading)

THICKENER AND VACUUM FILTER

(mg/1)

	Supernatant							Sludge						
Date	9/21	9/26	9/27	9/28	10/3	10/4	10/5	9/21	9/26	9/27	9/28	10/3	10/4	10/5
Day	Wed	Mon	Tue	Wed	Mon	Tue	Wed	Wed	Mon	Tue	Wed	Mon	Tue	Wed
COD-Total	24	20	24	20	24	28	35							
BOD-Total	1.9	0.2	1.6	1.4	1.7	1.7								
BOD-N Suppressed	1.5	0.2	2.1	1.5	0.2	2.0								
Total Solids	286	297	325	319	318	297	348		4.59%	4.68	4.28	4.78	4.85	4.53
Total Volatile Solids	34	66	69	48	60	45	36		2.70%	2.80	2.64	3.00	3.05	2.79
Total Susp. Solids	6	34	3	3	0	0	14							
Total Vol. Susp. Solids	3	28	0	0	0	0	8							
Capillary Suction Test								11.4	21.5	19.2	12.5	13.6	10.5	14.3
Volume, gal	25100*	14190	19260	12850	19920	11220	17710		8560		8670			13400

VACUUM FILTER

	Filtrate			Cake			Cond. Sludge		
Date	9/26	9/28	10/5	9/26	9/28	10/5	9/26	9/28	10/5
Day	Mon	Wed	Wed	Mon	Wed	Wed	Mon	Wed	Wed
COD-Total	563	1660	688						
BOD-Total	384	411							
BOD-N Suppressed	247	238							
Total Organic Carbon	143								
Total Solids	893	2050	921	12.2%	12.0%	11.9%			
Total Volatile Solids	460	1110	404	7.3%	7.4%	7.4%			
Total Susp. Solids	166	2820	512						
Total Vol. Susp. Solids	94	1740	318						
Capillary Suction Test							8.0	10.6	9.1

* Total Supernatant and Sludge

TABLE C-7
MEDFIELD - PHASE IIA (continuous loading)

MICROBIOLOGICAL INDICES

Date	9/14	9/15	9/16	9/19	9/20	9/21	9/22	9/23	9/26	9/27	9/28	9/29	9/30	10/3	10/4
Return Sludge															
Total No.Organisms (N)	216	193	179	196	130	105	93	13	86	88	79	96	59	76	108
Total No. Species (S)	10	9	8	8	8	8	7	7	8	9	8	8	7	7	7
Diversity Index ($\bar{H}$)	1.51	1.61	1.82	2.16	2.25	2.36	2.15	2.50	2.12	1.94	2.63	1.82	1.96	2.26	1.87
No. Organisms															
Vorticella	32	20	19	71	29	15	38	1	33	55	23	61	34	36	64
Colpoda & Euplotes	155	129	109	72	58	41	29		28	8	13	7	5	5	1
Micro Flagellates	1	2	1	3	3	2	2	5		3	9	1	3	6	8
Macro Flagellates	5	1	3	4	3	18	9	1	2	6	4	8	2	5	4
Rotifers	6	4	6	20	9	2	5	1	5	2	10	5	5	9	13
Diatoms	2	1						2	1	3	2	2			
Lionotes	6	7	7	6	7	7	2		2	1	2	1	1	2	3
Micro Ciliates															
Suctorians	3		4	3					1						
Nematodes	1	1			2	1		1		1					
Spirochetes	5	28	30	17	19	19	8	2	14	9	16	11	9	13	15
Mixed Liquor															
Total No.Organisms (N)	205	196	199	198	115	109	23	32	65	144	57	68	53	58	83
Total No. Species (S)	8	9	10	7	9	7	3	8	8	9	7	7	8	6	10
Diversity Index ($\bar{H}$)	1.81	2.03	1.95	2.11	2.07	1.93	.84	2.36	2.22	1.90	2.15	2.35	2.23	1.90	2.34
No. Organisms															
Vorticella	37	24	22	68	16	21	19	1	25	87	7	25	26	29	30
Colpoda & Euplotes	124	112	102	65	61	55		9	15	15	10	5	5	3	8
Micro Flagellates	2	7	3	3	1	2		1	2	2	1	5	1	2	2
Macro Flagellates	2	1	4	9	4	9		4	1	7	3	4	4	4	4
Rotifers	6	5	5	6	3	1	2	3	3	8	8	6	7	3	3
Diatoms		5	1		1		2		1	1	1		1		1
Lionotes	12	13	5	5	8	1		1	2			3	1		1
Micro Ciliates			1		1										
Suctorians	3	2	1							1					4
Nematodes								1		2					1
Spirochetes	19	27	55	42	20	20		12	16	21	27	20	8	17	29
Effluent															
Total No.Organisms (N)	21				92		33			118		24			33
Total No. Species (S)	10				7		8			11		11			8
Diversity Index ($\bar{H}$)	2.91				1.31		2.84			2.83		3.30			2.82
No. Organisms															
Ciliates	1				3		5			4		4			3
Green Filaments	1				1					11		2			
Micro Flagellates	2				4		5			10		2			6
Macro Flagellates	1						4			10		2			9
Scenedesmus	1				12		4			21		2			4
Colpoda	7						3			15		3			2
Pennates	3				2		8			39		4			4
Naviculum	3				69					2					
Rotifers	2									3		2			2
Parmecium	1				1		3			1		1			3
Nematodes							1					1			
Vorticella										2		1			

APPENDIX D

TABLE D-1

MEDFIELD - PHASE IIB (continuous loading)

SEPTAGE (mg/l)

Date	11/1	11/2	11/3	11/4	11/4	11/6	p.m. 11/6	11/7	$\bar{x}$
Day	Tue	Wed	Thur	Fri	Sat	Sun	Sun	Mon	
Volume, gal	11,010	11,281	7,933	11,062	11,150	9,993		10,238	10,380
% Daily Flow	3.67	4.04	2.46	4.10	4.76	4.18		3.88	
COD-Total	11,380	8,700	14,415	4,590	10,625	12,850	16,940	48,000	15,938
COD-Soluble	475	1,345	940	1,090	940	940		1,805	
BOD-Total	3,510	2,775	2,000	1,440	1,507	2,550			
BOD-N Suppressed	2,215	2,400	1,510	880	1,260	2,520		10,800	
Total Solids	10,500	4,170	8,280	3,030	5,220	6,695	10,520	47,275	
Total Volatile Solids	8,540	3,015	5,900	2,100	3,900	4,740	7,680	34,335	
Suspended Solids	9,115	3,030	6,890	2,100	4,020	5,435	9,255	45,510	
Volatile Susp. Solids	7,545	2,285	4,920	1,645	3,160	3,900	6,990	33,130	
Total Kjeldahl-N	125	174	273	132	195	258		792	278
Ammonia-N	68	70	70	80.	60	64		72	69
pH	6.9	7.6	6.9	7.3		7.4		7.2	
Temperature, °C	14	12	12	11		12		12	
Alkalinity	625		559		483	688		970	

TABLE D-2

MEDFIELD - PHASE IIB (continuous loading)

INFLUENT (mg/l)

Date	10/31	11/1	11/2	11/3	11/4	11/5	11/6	11/7	11/8	$\bar{x}$
Day	Mon	Tue	Wed	Thur	Fri	Sat	Sun	Mon	Tue	
Flow Rate, mgd	.288	.300	.279	.322	.270	.234	.239	.264	.403	.289
COD-Total	269		269	494	307	207	297	271	249	295
COD-Soluble	79		99	86	86	55	240	71	40	
BOD-Total		85	99	166	177		96	108	99	119
BOD-N Suppressed		62	69	94	113		57	69	72	77
Total solids		349	337	573	403	418	386	429	419	
TVS		131	195	308	194	186	265	192	193	
Suspended Solids		66	60	301	14	58	91	113	134	
Volatile Susp. Solids		60	58	231	13.5	55	86	101	88	
Total Kjeldahl-N			21	24	33	20	21	22	25	23.7
Ammonia-N	62.5	15	22	16	14	12	13	17	14	20.6
Nitrate-N		.48	.75	.54	.6	.5	.53	.63	.75	.59
pH			7.7	7.4	7.0	7.6		7.0	7.2	
Temperature, °C			14.0	14.0	15.0	15.0		15.0		
Alkalinity				149	154	125	130	122	114	

TABLE D-3

MEDFIELD - PHASE IIB

SECONDARY EFFLUENT (mg/l)

Date	10/31	11/1	11/2	11/3	11/4	11/5	11/6	11/7	11/8	$\bar{x}$
Day	Mon	Tue	Wed	Thur	Fri	Sat	Sun	Mon	Tue	
COD-Total	41.5		33.6	27.3	29.0	33.2	25.4	29.5	29.7	31.2
COD-Soluble	29.6		35.0	11.7	21.0	33.2	23.4	27.5	27.7	26.1
BOD-Total	1.1	4.4	2.7	1.8	2.7	3.2	1.6	2.7	2.2	2.5
BOD-N Suppressed	0.3	3.1	1.6	1.0	1.5	1.3	0.6	1.3	1.7	1.4
Total Solids	191.1	289.2	232.0	332.0	341.5	392.0	391.0	351.0	323.3	316.0
Total Vol. Solids	100.5	198.0	92.7	81.0	104.0	86.0	135.0	162.0	76.7	115.0
Suspended Solids	1.7	2.4	5.2	1.1	3.1	1.0	1.6	3.9	1.8	2.4
Volatile Susp.Solids	0.5	1.9	4.9	1.1	2.9	1.0	1.6	3.6	1.4	2.1
Ammonia-N	0.14	0.46	0.34	0.65	0.32	0.16	0.19	0.66	0.41	0.37
Nitrate-N	9.5	12.5	13.0	11.0	12.0	14.0	14.0	15.0	14.5	12.8
pH			7.7	7.5	7.1	7.4			7.1	
Temperature, °C			13.0	14.0	15.0					

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TABLE D-4

MEDFIELD - PHASE IIB

MIXED LIQUOR (mg/1)

Date	11/1	11/2	11/3	11/4	11/5	11/6	11/7	11/8	11/9	11/1	11/2	11/3	11/4	11/5	11/6	11/7	11/8	11/9
Basin No.					# 4								# 1					
Total Solids	7690	7940	7940	7640	8150	8360	8180	7990	7740	7380	7800	7690	7330	7970	8360	8190	8630	8980
Total Volatile Solids	4660	4890	4920	4750	4960	5100	4890	5010	4760	4430	4830	4700	4560	4840	5100	5010	5410	5630
Suspended Solids	7480	7700	7660	7330	7790	8030	7890	7660	7470	7180	7570	7530	7030	7640	8030	7870	8210	8740
Volatile Susp. Solids	4560	4720	4840	4680	4820	4960	4860	4860	4640	4340	4790	4690	4410	4710	4960	4940	5310	5480
pH	6.8	7.9	7.4	7.1	7.5		7.0		7.0									
Temperature, °C	13.5	13.0	14.0	14.5	15.0		15.0	15.0	16.0									
Alkalinity	167			162		300	269	200	147	170					275	312	206	166
Settlometer																		
5 min	920	950	930	940	940	910	900	910	890	930	940	920	920	900	750	900	900	940
10	840	900	860	850	850	860	840	820	770	860	870	820	790	800	600	820	800	870
15	750	830	790	780	750	770	770	740	640	770	800	725	650	700	520	740	700	810
20	680	770	710	675	660	690	700	660	560	700	740	640	550	620	470	660	620	740
25		705	640	630	600	630	650	600	510	610	670	570	510	550	440	600	570	680
30	560	650	585	570	550	575	600	540	475	580	620	510	480	510	410	550	520	620
45	460	520	470	475	450	450	500	450	410	460	490	420	400	430	350	460	450	500
60	420	450	430	430	400	430	450	400	380	420	420	370	370	390	340	420	410	430
Settling column																		
5 min	54.0	34.9	28.6	28.6	28.6		25.4	28.6	44.5									
10	130.2	106.4	117.5	104.8	111.1		85.7	79.4	133.4									
15	208.0	177.8	200.0	190.5	196.9		152.4	149.2	228.7									
20	288.9	247.7	288.7	273.1	285.1		222.3	222.3	308.0									
25	396.9	336.6	374.7	377.8	362.0		298.5	298.5	396.9									
30	479.4	417.5	460.4	460.4	441.3		368.3	374.7	485.8									
45	717.6	654.1	700.0	685.8	666.8		562.0	587.4	746.1									
60	930.3	857.3	420.8	892.2	822.3		746.1	771.5	965.2									

TABLE D-5
MEDFIELD - PHASE IIB
DISSOLVED OXYGEN

Date	11/1	11/1	11/2	11/2	11/2	11/3	11/3	11/4	11/4	11/5	11/5	11/5	11/6	11/7	11/7	11/7	11/8	11/9	11/10
Day	Tue	Tue	Wed	Wed	Wed	Thur	Thur	Fri	Fri	Sat	Sat	Sat	Sun	Mon	Mon	Mon	Tue	Wed	Thur
Time	7:30 a.m.	1:00 p.m.	8:30 a.m.	12 noon	3:50 p.m.	8:30 a.m.	12:20 p.m.	8:00 a.m.	12 noon	9:30 a.m.	1:30 p.m.	3:45 p.m.	9:00 a.m.	9:00 a.m.	1:00 p.m.	3:00 p.m.	7:30 a.m.	7:30 a.m.	7:30 a.m.
D.O. Uptake																			
Basin # 3		9.0	10.8			13.8		20.4		10.8			17.7	11.7			11.7	13.8	
# 1		22.8	11.4			10.5		20.4		23.1			20.7	15.0			12.6	14.1	
Dissolved Oxygen																			
Basin #1	6.6	1.7	3.3	1.5	0.9	2.8	1.5	1.4	1.6	2.6	1.1	0.7	3.5	0.3	0.8	0.4	3.9	3.3	5.0
#2	6.2	5.0	4.7	4.1	2.9	4.0	2.5	3.8	3.0	3.0	2.3	2.5	4.3	3.7	3.3	2.6	5.0	4.7	5.2
#3	5.6	4.6	3.9	3.3	2.2	2.9	2.0	2.9	2.3	2.2	1.8	1.6	3.0	3.3	2.4	1.7	4.0	3.9	4.3
#4	5.2	4.2	3.1	2.7	1.3	2.2	1.3	2.1	2.0	1.7	1.2	1.2	2.5	2.7	1.9	1.1	3.3	3.2	3.7
Clarifier	3.3	3.6	1.6	1.2	0.8	0.8	0.7	0.8	0.7	0.2	0.2	0.2	0.9	0.9	0.6	0.4	1.1	1.4	1.6

TABLE D-6
MEDFIELD - PHASE IIB
SECONDARY SLUDGE

Date	11/1	11/2	11/3	11/4	11/5	11/6	11/7	11/8	11/9
Day	Tue	Wed	Thur	Fri	Sat	Sun	Mon	Tue	Wed
Total Solids	11700	9200	8300	12010	9020	10370	10960	8210	9390
Total Volatile Solids	7300	5610	5140	7360	5370	6290	6760	5070	5730
Suspended Solids	11460	8960	8040	11570	8600	9010	10660	7900	9130
Volatile Suspended Solids	7170	5600	5030	7160	5230	6200	6700	4970	5690
Flow Rate, mgd	.419	.344	.767	.408	.441	.431	.412	.463	
Capillary Suction Test	10.3	7.5	7.0	7.5	8.3	8.0	7.9	6.4	7.3

TABLE D-7
MEDFIELD - PHASE IIB
THICKENER AND VACUUM FILTER

THICKENER

	Supernatant			Sludge		
Date	11/2	11/3	11/8	11/2	11/3	11/8
Day	Wed	Thur	Tue	Wed	Thur	Tue
COD-Total	39.5	35.0	31.4			
BOD-Total	3.4	2.9	7.3			
BOD-N Suppressed	1.7	2.2	2.3			
Total Solids	280	290	340	3.12%	3.18	5.66
Total Volatile Solids	53	68	93	1.14%	1.17	3.61
Total Susp. Solids	2.0	3.0	16			
Volatile Suspended Solids	2.0	3.0	7.0			
Capillary Suction Test				8.4	5.4	7.1
Volume	38170*	19200*	40090*	10360	4670	

VACUUM FILTER

	Filtrate			Cake			Cond. Sludge		
Date	11/3	11/4	11/9	11/3	11/4	11/9	11/3	11/4	11/9
Day	Thur	Fri	Wed	Thur	Fri	Wed	Thur	Fri	Wed
COD-Total	1931	875	617						
BOD-Total	426	303	285						
BOD-N Suppressed	193	144	137						
Total Solids	2330	1000	850	11.9%	12.8%	10.8%	5.5%	5.7%	6.6%
Total Volatile Solids	1300	475	450	7.2%	4.6%	3.9	3.2%	2.1%	2.4%
Total Susp. Solids	1790	564	400						
Volatile Susp. Solids	1140	381	250						
Capillary Suction Test							6.8	7.1	14.1

* Total Supernatant and Sludge

TABLE D-8
MEDFIELD - PHASE IIB
MICROBIOLOGICAL INDICES

	BASIN #1					EFFLUENT	
Date	11/1	11/3	11/5	11/7	11/9		11/8
Total No. Organisms	88	82	75	96	66		14
Total No. Species	7	8	6	7	7		5
Diversity Index	2.26	2.15	1.9	1.72	2.06		2.07
No. of Organisms							
Vorticella	33	32	39	62	34	Ciliates	
Colpoda and Euplotes	15	9	4	12	4	Green Filaments	
Micro Flagellates	12	21	11	6	11	Micro Flagellates	3
Macro Flagellates	20	16	16	8	7	Macro Flagellates	4
Rotifers	3	1	4	6	8	Scenedesmus	
Diatoms				1		Colpoda	
Lionotes						Pennates	5
Micro Ciliates						Naviculum	1
Suctorians		1	1	1	1	Rotifers	1
Nematodes		1				Paramecium	
Spirochetes	4	1			1	Nematodes	
						Vorticella	

TABLE D-9

MEDFIELD - HEAVY METALS

INFLUENT, EFFLUENT AND SEPTAGE

Phase	I						IIA						IIB		
Date	8/24	8/26	8/31	9/2	9/7	9/9	9/14	9/16	9/21	9/23	9/28	9/30	11/2	11/5	11/9
Septage Loading %							2.61	2.03	1.85	2.14	1.88	1.69	4.04	4.76	
Influent															
Copper (mq/l)	.12	.15	.08	.16	.14	.15	.27	.37	.18	.25	.09	.16	.07	.09	.07
Nickel	.15	.07	.14	.09	.06	.11	.15	.28	.09	.28	.11	.14	.02	.04	.07
Chromium	0	0	.24	.75	.09	.12	.09	.15	.10	.14	.10	.14	.07	.07	.08
Zinc	.90	.18	.41	.32	.23	.17	.17	.33	.97	8.00	.13	.32	.28	.24	.17
Cadmium	0	.04	.02	.05	.05	.05	.01	.04	.01	.01	.02	.03	0	.13	.02
Lead	.50	.64	.61	.74	.46	.57	.36	.19	0	.38	.10	.14	.40	.19	.20
Secondary Effluent															
Copper (mq/l)	.04	.05	.05	.07	.07	.06	.23	.14	.15	.24	.03	.04	.04	.03	.03
Nickel	.22	.07	.07	.13	.05	.05	.13	.10	.10	.10	.11	.10	0	0	.02
Chromium	.40	.10	.17	0	.15	.07	.21	.13	.10	.12	.10	.10	.09	.04	.02
Zinc	.43	.10	.50	.09	.12	.09	.13	.23	.10	3.56	.09	.08	.94	.14	.14
Cadmium	0	0	.02	.05	.02	.07	.01	.01	.01	.02	.02	.02	0	.01	.01
Lead	.20	.08	.10	.32	.10	.10	0	0	0	0	.10	.10	.09	.10	.06
Septage															
Copper (mq/l)							6.44	2.56	2.49		1.83	7.52	3.42	1.44	
Nickel							.25	.17	.19		.34	.50	.38	.13	
Chromium							.45	1.30	.21		.33	.70	.43	.11	
Zinc							7.30	2.28	2.17		3.29	8.05	8.38	2.64	
Cadmium							.07	.03	.04		.05	.06	.08	.04	
Lead							.50	1.50	.95		.27	1.20	1.80	1.00	

TABLE D-10

MEDFIELD - HEAVY METALS

THICKENER AND VACUUM FILTER

Phase	I						IIA						IIB			
Date	8/30	8/31	9/6	9/9	9/15	9/16	9/22	9/26	9/27	9/28	10/3	10/5	11/2	11/3	11/8	11/9
Septage Loading %							2.17	1.50	1.90	1.88	1.60		4.04	2.46	4.76	
Thickener Supernatant																
Copper (mg/l)	.07	.06	.04		.11		.20	.06	.03	.24	.33	.09	.03	.02	.04	
Nickel	.10	.10	.08		.09		.11	.11	.13	.14	.10	.13	.03	.03	.02	
Chromium	0	0	0		.04		.10	.34	1.78	.32	.10	.44	.09	.03	.04	
Zinc	.06	.56	.19		.12		2.32	.51	.96	2.53	.73	.19	.29	.26	.28	
Cadmium	0	.05	.05		.01		.01	.01	.03	.03	.01	.04	0	0	.02	
Lead	.71	0	1.07		0		0	.17	.39	0	.25	.44	.10	.15	.09	
Vacuum Filter Filtrate																
Copper (mg/l)		.11		.15		.18		.15		.20		.55		.85		.25
Nickel		.02		.09		.20		.10		.11		.10		.06		.08
Chromium		.15		0		.10		.15		.26		.15		.09		.07
Zinc		.89		.18		2.88		2.90		1.67		.54		2.04		.67
Cadmium		0		.05		.02		.02		.04		.01		.03		.04
Lead		.38		.30		0		.20		.83		.50		.70		.78
Cake																
Copper (mg/kg of Dry Cake)		1260		1190		1280		631		952				668		802
Nickel		235		102		201		66		83				89		76
Chromium		440		285		193		132		199				80		183
Zinc		1540		1179		532		1447		795				1384		1731
Cadmium		29		68		16		26		17				27		38
Lead		1759		1995		242		197		580				606		637

APPENDIX E

TABLE E-1
MEDFIELD - PHASE IIIA (shock loading)
SEPTAGE (mg/l)

Date	10/14	10/15	10/16
Day	Fri	Sat	Sun
Volume, gal	5000	5000	6700
Percent of Flow	1.5	1.9	2.0
Loading Time	9:00am	9:20am	9:10am
COD-Total	28950	29130	60000
COD-Soluble	1790	1690	
BOD-Total	6080	5100	
BOD-N Suppressed	3980	4640	
Total Solids	16700	8850	
Total Volatile Solids	13310	6890	
Suspended Solids	15100	6930	
Volative Suspended Solids	12180	5550	
Ammonia-N	56	45	71
Total Phosphorus	155	165	120
pH	6.9		6.9
Alkalinity	480	440	

TABLE E-2
MEDFIELD - PHASE IIIA (shock loading)
INFLUENT (mg/l)

Date	10/4	10/15	10/16	10/17	10/18
Day	Fri	Sat	Sun	Mon	Tue
Flow Rate, mgd	.33	.27	.34	.37	
COD-Total	295		86	108	132
Total Solids	479		277	335	356
Total Volatile Solids	220		65	105	75
Suspended Solids	146		31	112	10
Volatile Susp. Solids	120		26	66	10
Ammonia-N	13.1				3.6
Total Phosphorus	14			6.4	7.3
pH	7.4		7.3	6.9	7.1
Temperature, °C					
Alkalinity	165		104	67	
BOD-Total	84			51	
BOD-N Suppressed	51			36	

TABLE E-3

MEDFIELD - PHASE IIIA (shock loading)

SECONDARY EFFLUENT (mg/1)

Date	Friday 10/14					Friday 10/14											Saturday 10/15				
	a.m.					p.m.											a.m.			p.m.	
Time	9:00	10:00	11:00	12:00	1:00	2:00	2:30	3:00	3:30	4:30	5:30	6:30	7:30	8:30	9:30	10:30	9:20	10:20	11:20	12:20	1:20
ΔT after shock, hrs.	0	1	2	3	4	5	5.5	6	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	0	1	2	3	4
COD-Total	31.5	35.4	27.6	35.4	27.6	51.2	43.3	23.6	55.1	31.5	31.5	23.6	51.2	51.2	35.3	51.2		27.5	27.5	27.5	31.4
COD-Soluble	27.6	15.5		27.6	27.6	27.6	39.4	19.7	31.5	23.6	15.7	11.8	15.7	23.6	15.7	11.8					
BOD-Total		2.5	4.2	2.0													2.0	1.6	2.0		
BOD-N Suppressed			0.4	0.5													0.9	0.8	0.8		
Total Solids	351	329	317	317	261	333	341	315			332			341		373	325	297	300	317	325
Total Volatile Solids	90.7	93.3	44	48	34.7			56									69.3	32.0	62.7	58.7	73.3
Suspended Solids	7.2	6.8	7.4	4.4	7.0												5.0	1.8	5.6	2.2	6.8
Volatile Susp. Solids	6.0	5.4	7.0	4.0	6.6												2.8	1.2	3.8	1.4	4.2
Ammonia-N	0.0	0.0	0.0	0.0	<.1	<.1	<.1	<.1									<.1	<.1			<.1
Nitrate-N	14.0	14.1	14.1	14.1	10.8	14.0	14.5	13.3	14.0	14.1	14.0	14.7	14.0		14.2	15.0	12.0	10.8	11.8		
Total Phosphorus	.8	1.0	1.0	.9	.9	.9	.9	.9	.9	.9	.9	.9	.8	.9	.8	.8	.8	.7	.9		1.0
pH	7.5	7.2	7.3	7.0	7.2	7.0	6.9		6.9	6.9							7.4	7.3	7.4	7.2	7.4
Temperature, °C	15	15	14	14	14												12	14	14	15	15
Alkalinity	78	72	77	75																74	72

(continued)

TABLE E-3 (continued)

Date			Saturday 10/15 p.m.													Sunday 10/16 a.m.					
Time	2:20	3:20	4:20	5:20	6:20	7:20	8:20	9:20	10:20	11:20	12:20	1:20	2:20	3:20	4:20	5:20	6:20	7:20	8:30	9:10	10:10
Δ T After Shock, hrs.	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0			0	1.0
COD-Total	23.9	51.0	27.9	31.9	12.0	15.6	19.9	23.9	23.9	23.9			19.9			8.0				31.0	35.3
BOD-Total																			.9		.9
BOD-N Suppressed																			.2		
Total Solids	326	300		332			331			335			325			319				320	321
Total Volatile Solids		52.0																		64.0	61.3
Suspended Solids		4.2																		5.8	6.8
Volatile Susp. Solids		3.2																		3.8	4.2
Ammonia-N	<.1	<.1	<.1			<.1			<.1				<.1						<.1		<.1
Nitrate-N	13.0	12.0	11.5	12.3	12.1	12.2	11.0	12.0	12.3	12.0			12.0			11.3			11.5	10.0	9.1
Total Phosphorus	1.0		1.0		1.0		1.2	1.2												1.0	1.0
pH	7.2																			7.3	7.4
Temperature, ^{o}C	14																			13	13
Alkalinity		79																	79		79

(continued)

TABLE E-3 (continued)

Date	Sunday 10/16									Sunday 10/16						Monday 10/17					
	a.m.				p.m.						p.m.						a.m.				
Time	11:10	12:10	1:10	2:10	3:10	4:10	5:10	6:10	7:10	8:10	9:10	10:10	11:10	12:10	1:10	2:10	3:10	4:10	5:10	6:10	7:10
ΔT After Shock, hrs.	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0
COD-Total	47.1	12.1	20.2	28.3	36.4	28.3	28.3	40.5	36.4	28.3	20.2	28.3	32.4	24.3	20.2	24.3	36.4		28.3		
BOD-Total		0.3	1.8		2.0																.2
BOD-N Suppressed		0.3	0.4		0.4																0
Total Solids	319	331	327		313					345		327				353			341		
Total Volatile Solids	61.3	44.0	50.7		50.7																
Suspended Solids	5.4	3.0	6.6		6.6																
Volatile Susp. Solids	3.4	1.4	3.8		3.8																
Ammonia-N	<.1	<.1	<.1		<.1		<.1		.1			.1			.1			.1	.1		.1
Nitrate-N	8.8	10.3	10.0	9.5	9.0	8.6	8.2	7.6	7.4	7.3	6.9	6.7	6.5		6.1			5.2	5.0		4.0
Total Phosphorus	0.9	0.8	1.0	0.9	0.8	0.8	0.8	0.8						0.8			0.8			0.8	
pH	7.4	7.5	7.6		7.6																
Temperature, °C	14	15	15		14																
Alkalinity	78																				

(continued)

TABLE E-3 (continued)

Date	Monday 10/17								Tue 10/18
			a.m.				p.m.		a.m.
Time	8:00	8:30	9:00	10:00	11:00	12:00	1:00	7:30	8:00
ΔT After Shock, hrs.	22.8	23.3	23.8	24.8	25.8	26.8	27.8	34.3	46.8
COD-Total	39.8		40.0	27.9	53.7	25.9		19.9	23.9
BOD-Total								3.1	0.9
BOD-N Suppressed								0.3	0.4
Total Solids	344	319						268	279
Total Volatile Solids		36						67	83
Suspended Solids		5.0						6.2	1.2
Volatile Susp. Solids		2.4						4.6	1.2
Ammonia-N		0.4			0.11	0.04		0.06	0.12
Nitrate-N	3.8		4.0		3.5	3.2		4.8	4.2
Total Phosphorus	0.9		1.0	0.9	1.0	0.8		0.9	0.9
pH	7.0								7.1
Temperature, °C	14								13
Alkalinity								94	

TABLE E-4

MEDFIELD - PHASE IIIA (shock loading)

DISSOLVED OXYGEN (mg/1)

Date	9:00 ⇩ Friday 10/14								9:20 ⇩ Saturday 10/15												
Time	a.m. 9:00	10:00	11:00	12:13	12:45	2:00	p.m. 3:00	4:00	9:20	9:50	10:20	a.m. 11:05	11:20	12:20	12:50	1:20	2:20	p.m. 2:50	3:15	3:45	4:45
ΔT After Shock	0	1.0	2.0	3.22	3.75	5.0	6.0	7.0	0	0.5	1.0	1.75	2.0	3.0	3.5	4.0	5.0	5.5	5.9	6.4	7.4
Basin #1	6.2	2.6	2.8		2.4	2.2	2.6	2.1	5.3	1.2	1.2	1.9	2.8	1.6	1.4	1.6	1.1	0.7	1.1	0.3	1.1
#2	5.9	6.2	4.7		2.4	3.3	4.3	3.8	4.9	4.7	4.8	4.7	4.9	4.6	4.6	4.3	4.5	4.1	3.6	4.1	5.0
#3	5.7	6.4	4.8		2.8	3.0	3.5	3.5	4.7	4.7	4.4	4.2	4.1	4.2	4.0	4.2	3.7	3.9	3.5	3.7	4.2
#4	5.5	6.1	4.8		2.8	2.6	3.2	3.3	4.3	3.9	3.8	3.7	3.5	3.6	3.8	3.2	3.2	3.6	3.2	3.0	3.6
Clarifier	3.5	4.2		2.9	2.8	1.9	2.0	2.4	2.8	2.1	2.3	2.8	2.9	2.6		2.4	2.2	2.4	2.2	2.5	2.3

Date	9:00 ⇩ Sunday 10/16																				
Time	8:55	9:25	9:55	a.m. 10:25	10:55	11:25	11:55	12:25	12:55	1:25	1:55	2:25	2:55	3:25	p.m. 3:55	4:25	4:55	5:25	5:55	8:25	8:45
ΔT After Shock	0	.25	.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	11.25	11.58
Basin #1	6.2	5.8	0.3	0.4	0.5	0.5	0.6	0.7	0.8	0.6	0.6	0.7	0.8	0.8	0.8	0.8	0.9	1.2	1.6	2.1	2.1
#2	6.2	6.0	5.3	3.1	1.4	0.6	0.7	1.1	1.1	1.7	1.9	1.2	1.6	1.8	1.9	1.9	2.0	1.7	1.6	2.2	2.2
#3	5.0	5.2	5.0	3.0	1.7	0.4	0.4	0.2	0.6	0.6	0.6	0.5	0.5	0.7	0.8	1.1	1.0	1.0	1.1	1.4	1.4
#4	4.7	4.8	4.5	2.7	0.7	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.5	0.6	0.6	0.5	1.1	1.0
Clarifier	2.7	2.7	2.8	2.7	2.1	1.5	0.5	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.5

Date	Monday 10/17			Tuesday 10/18
Time	a.m. 9:20	10:30	p.m. 7:25	a.m. 7:25
ΔT After Shock	24.17	25.33	34.25	46.25
Basin #1	3.9	1.6	3.0	4.9
#2	1.9	2.9	2.8	4.2
#3	1.2	2.1	2.2	2.8
#4	0.5	1.1	1.5	2.0
Clarifier	0.3	0.8	0.7	1.0

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TABLE E-5

MEDFIELD - PHASE IIIA (shock loading)

MIXED LIQUOR BASIN 1 AND 4 (mg/1)

Date	10/13	10/14						10/15						10/16						10/17	10/18
Time	a.m. 9:00	9:20	a.m. 10:20	11:20	p.m. 12:20	1:20	3:20	a.m. 9:20	10:20	11:20	12:20	p.m. 1:20	3:20	a.m. 9:10	10:10	11:10	12:10	p.m. 1:10	3:10	a.m. 7:30	a.m. 7:30
Total Solids	8230	8080	8150	8150	8050	8060	8190	8050	8270	8340	8480	8230	8680	8320	8640	8930	8990	8660	9140	9460	9030
Total Volatile Solids	4820	4670	4840	4890	4650	4750	4840	4200	4880	4920	5050	4930	5160	4930	5090	5300	5330	5160	[illegible]	5660	5380
Suspended Solids	7970	7750	7830	7840	7740	7770	7890	7780	7980	8050	8180	7910	8370	8010	8320	8620	8630	8350	8820	9160	8720
Volatile Susp. Solids	4780	4580	4720	4750	4540	4650	4740	4120	4840	4830	5010	4910	5110	4880	5030	5260	5290	5120	5360	5650	5350
pH	7.1	7.1	6.9	7.1	6.9	6.8		7.2	7.3	7.4	7.2	7.3	7.2	7.2	7.2	7.4	7.5	7.6	7.6	6.9	7.0
Temperature, °C	15	15	15	14	14	14		13	13	14	14	14	14	12	13	14	15	15	14	14	13
Alkalinity	190	185	170	175	260	270								220	210	210				230	
D.O. Uptake*	7.8	8.9	8.4	8.0	8.4	9.6	15.6 ↑ 2pm ↓	7.5	8.4	10.5	8.3	9.0	9.3	8.1	8.4	20.6	22.8	17.4	18.2	13.3	14.8
Settlometer+																					
5 minutes	945	940	940	930	920	940	930	945	940	920	940	940	900	940	910	930	950	880	920	950	940
10 minutes	880	880	880	870	850	880	845	890	880	800	890	880	810	885	820	865	900	765	850	900	880
15 minutes	820	820	810	810	780		750	840	820	710	830	815	730	830	735	810	830	675	790	840	820
20 minutes	750	760	740	730	700	740	670	780	760	640	765	750	660	775	660	740	770	600	720	765	760
25 minutes	695	700	680		630	680	600	725	700	575	715	695	600	720		690	710	550	660	730	700
30 minutes	640	645	620	580	580	620	550	670	650	530	660	640	550	665	560	630	650	510	610	680	640
45 minutes	520	520	500	500	470	470	460	540	530	460	530	520	480	550	480	515	550	450	500	555	520
60 minutes	450	450	440	430	420	440	420	470	460	415	460	460	430	480	450	460	480	410	450	480	450

* Basin #3
+ Basin #4 near discharge point

TABLE E-6

MEDFIELD - PHASE IIIA (shock loading)

MIXED LIQUOR BASIN #1 (mg/l)

Date	10/16						10/17	10/18
	a.m.			p.m.			a.m.	a.m.
Time	9:10	10:10	11:10	12:10	1:10	3:10	7:30	7:30
D.O. Uptake	8.4	42.6	57.6	43.2	32.4	30.3	22.2	11.7
Settlometer								
5 minutes			900	930	900	940	940	940
10 minutes			800	860	780	900	880	880
15 minutes			730	740	695	850	810	815
20 minutes			640	650	610	790	750	750
25 minutes			590	590	560	740	690	685
30 minutes			560	550	520	690	640	630
45 minutes			490	500	460	560	515	500
60 minutes			480	460	420	480	450	450
Total No. Organisms		102				83	90	65
Total No. Species		9				10	90	6
Diversity Index		2.41				2.75	2.20	2.75
No. Organisms								
Vorticella		4				9	3	7
Colpoda & Euplotes		27				15	28	23
Micro Flagellates		6				4	1	
Macro Flagellates		23				24	28	15
Rotifers		4				8	7	12
Diatoms		1				1		
Lionotes		33				16	21	7
Micro Ciliates						1		
Suctorians		1				1	1	
Nematodes								
Spirochetes		3				4	1	1

TABLE E-7
MEDFIELD - PHASE IIIA
SECONDARY SLUDGE (mg/l)

Date	10/13	10/14	10/15	10/16	10/17	10/18
Total Solids	10860	10200	15700	12020	16400	14300
Total Volatile Solids	6440	5940	9160	7130	9870	8670
Flow Rate, mgd	.428	.320	.400	.349	.420	
Capillary Suction Test		7.4	8.1	7.7	9.7	9.3

TABLE E-8
MEDFIELD - PHASE IIIA (shock loading)

THICKENER AND VACUUM FILTER

	THICKENER				VACUUM FILTER		
	Supernatant		Sludge		Filtrate		Cake
Date	10/17	10/19	10/17	10/19	10/18	10/20	10/18
COD-Total	17.9				359		
BOD-Total	1.2				180		
BOD-N Suppressed	0.7				50		
Total Solids	336		5.0%		564		13.0%
Total Volatile Solids	54		1.9%		225		8.1%
Total Susp. Solids					198		
Total Vol. Susp. Solids					128		
Capillary Suction Test			9.8				
Volume, gal	14350	11250			7940	4847	

TABLE E-9

MEDFIELD - PHASE IIIA (shock loading)

MICROBIOLOGICAL INDICES

Date	10/13	10/14						10/15				
			a.m.			p.m.				a.m.		p.m.
Time		9:20	10:20	11:20	12:20	1:20	3:20	9:20	10:20	11:20	12:20	1:20
ΔT After Shock		0	1	2	3	4	6	0	1	2	3	4
Mixed Liquor												
Total No. Organisms	205	191	136	159	146	121	166	138	154	117	128	121
Total No. Species	8	9	9	10	9	7	6	8	9	8	9	7
Diversity Index	1.57	2.06	2.11	1.86	1.95	1.94	1.94	2.12	2.13	1.99	2.09	2.00
No. Organisms												
Vorticella		4	2		1	5	3	7	1	2	4	3
Colpoda & Euplotes		28	16	14	17	27	33	33	34	20	20	27
Micro Flagellates		6	4	3	2	4	8	1	8	2	1	
Macro Flagellates		29	16	35	34	15	25	22	25	15	21	18
Rotifers		12	7	3	10	5	11	7	9	10	9	9
Diatoms		1	2	1	1			1	1	1	1	
Lionotes		104	76	92	77	64	86	63	72	64	67	60
Micro Ciliates		1		1								
Suctorians				1								
Nematodes			1	1	1				1	1	2	2
Spirochetes		6	13	8	3	1		4	3	3	3	2
Effluent												
Total No. Organisms		44					44	58				
Total No. Species		7					7	7				
Diversity Index		2.13					1.82	2.24				
No. Organisms												
Ciliates		7					27	28				
Micro Flagellates		4					2	3				
Macro Flagellates		4					4	10				
Scenedesmus		2						3				
Colpoda							1	3				
Pennates		23					7	7				
Naviculum		3					1	4				
Nematodes							2					

(continued)

TABLE E-9 (continued)

Date				10/16				10/17	10/18
Time	3:20	9:10	a.m. 10:10	11:10	p.m. 12:10	1:10	3:10	a.m. 7:30	a.m. 7:30
ΔT After Shock	6	0	1	2	3	4	6		
Mixed Liquor									
Total No. Organisms	104	95	102	105	90	95	89	66	55
Total No. Species	8	10	9	9	9	9	9	8	7
Diversity Index	1.96	2.60	2.40	2.41	2.43	2.46	2.38	2.49	1.94
No. Organisms									
Vorticella	2	2	3	1	2	2	2	3	4
Colpoda & Euplodes	22	25	28	31	27	29	25	22	22
Micro Flagellates	2	6	3	6	4	5	3	5	
Macro Flagellates	19	17	22	31	19	21	18	18	22
Rotifers	3	6	4	6	5	5	6	4	1
Diatoms	1	2	3	2	2	2	2	2	1
Lionotes	53	29	34	23	27	26	30	10	3
Micro Ciliates		1							
Suctorians		1							
Nematodes			3	1	1	1	1		2
Spirochetes	2	6	1	4	3	4	2	2	
Effluent									
Total No. Organisms	42	44					44	27	17
Total No. Species	6	6					5	6	3
Diversity Index	2.14	2.29					1.23	2.31	1.58
No. Organisms									
Ciliates	19	15					32	7	5
Micro Flagellates	4								
Macro Flagellates	10	9					2	1	6
Scenedesmus	4	2						3	
Colpoda		2					8	6	6
Pennates	3	9					1	8	
Naviculum	2	7						2	
Nematodes									

APPENDIX F

TABLE F-1

MEDFIELD - PHASE IIIB (shock loading)
SEPTAGE (mg/1)

Date	11/14	11/15	11/16	11/17
Day	Mon	Tue	Wed	Thur
Volume, gal	7770	7780	7780	10000
% of Flow	2.5	2.4	2.4	3.1
COD-Total	18810	23700	33460	32870
COD-Soluble	870		1580	3540
BOD-Total	3600		4500	7200
BOD-N Suppressed	3000	3980	3325	5625
Total Solids	12750	11640	16270	15830
Total Volatile Solids	9720	8880	12240	12050
Suspended Solids	11870	10480	14930	14180
Volatile Susp. Solids	9170	8110	11270	10870
Total Kjeldahl-N	319	373	377	532
Ammonia-N	72			280
Alkalinity		428	358	346

TABLE F-2

MEDFIELD - PHASE IIIB (shock loading)
INFLUENT (mg/1)

Date	11/14	11/15	11/16	11/17
Day	Mon	Tue	Wed	Thur
Flow Rate, mgd	.314	.330	.323	.322
COD-Total		240	220	
COD-Soluble		59.1	94.5	
Total Solids	460	347	352	
Total Volatile Solids	128	157	128	
Suspended Solids	70	122	70	
Volatile Susp. Solids	62	92	62	
Total Kjeldahl-N	21.8	21.3	19.3	
Ammonia-N			23	
Nitrate-N		0.5	0.7	
Temperature, °C	14		14	15
Alkalinity	150	132	130	
BOD-Total	69	80	67	
BOD-N Suppressed	45	60	45	

TABLE F-3

MEDFIELD - PHASE IIIB (shock loading)

SECONDARY EFFLUENT (mg/1)

Date			Monday 11/14												Tuesday 11/15						
Time	a.m. 7:20		9:00	10:00	11:00	p.m. 12:00	2:00	4:00	5:00	6:00	8:00	11:00	a.m. 2:00	5:00	7:30		9:30	10:30	11:30	p.m. 12:30	2:30
ΔT After Shock, hrs		SHOCK LOADING @ 8:00 a.m.	1.0	2.0	3.0	4.0	6.0	8.0	9.0		12.0	15.0	18.0	21.0	23.5	SHOCK LOADING @ 8:30 a.m.	1.0	2.0	3.0	4.0	6.0
COD-Total	51.2		43.3	47.2	39.4	47.2	55.1	51.2	35.9		43.8	43.8			43.3		47.2	43.3	43.3	27.6	27.6
COD-Soluble	15.8		27.6	23.6		39.4	39.4	31.5	19.9		12.0	12.0			27.6		23.6	23.6	19.6	19.7	19.7
BOD-Total	3.8		4.0	3.6	3.4	4.5	4.6	4.3		3.5					3.1		3.4	3.3	2.4	2.9	4.1
BOD-N Suppressed	1.4		1.6	1.6	1.7	1.7	1.3	2.1		1.6					0.8		0.8	0.8	0.7	0.7	1.4
Total Solids	463		443	437	423	461	456	473		416					319		332	396	325	397	381
Total Volatile Solids	98.7		72.0	68.0	78.7	216	188	232		125					64.0		59.0	63.0	65.0	97.0	108
Suspended Solids	12.4		8.4	6.4	10.0	10.8	13.2	14.0		13.6					12.8		14.0	12.0	7.2	6.8	8.8
Volatile Susp. Solids	7.6		5.8	5.6	6.0	10.4	12.0	14.0		12.4					12.0		13.2	10.8	7.2	4.0	6.0
Total Kjeldahl-N	1.7						2.0								1.7						
Ammonia-N	0.7		1.1	1.1	0.4	1.1	1.0	1.3		0.3	0.3	0.3	0.3	0.4	0.3		.27	.15	.15	.30	.30
Nitrate-N	14.2		15.1	15.0	15.1	14.0	15.0	14.9		16.2	16.0	15.9	15.5		13.3		13.7	14.4	14.6	14.0	14.1
Temperature °C	13																				
pH	7.8														7.6						
Turbidity	5.0		4.6	4.9	4.8	5.2	4.4	5.5		4.8					3.3		3.0	3.0	3.5	2.5	3.6

(continued)

TABLE F-3 (continued)

Date	Tuesday 11/15														SHOCK LOADING @ 8:30a.m.	Wednesday 11/16					
							p.m.										a.m.			p.m.	
Time	4:00	4:30	5:00	7:00	8:00	9:00	10:00	11:00	1:00	3:00	4:00	5:00	6:00	7:30		9:30	10:30	11:30	12:30	2:30	4:30
ΔT After Shock, hrs	7.5	8.0	8.5	10.5	11.5	12.5	13.5	14.5	16.5	18.5	19.5	20.5	21.5	23.0		1.0	2.0	3.0	4.0	6.0	8.0
COD-Total	27.6	55.1		35.4			27.6							27.6		31.5	35.4	47.2	43.3	47.2	55.1
COD-Soluble		11.8												11.8		19.7	27.6	31.5	27.6	31.5	35.4
BOD-Total		4.8												3.4		3.2	2.9	3.5	3.4	2.2	3.7
BOD-N Suppressed		3.6												1.9		1.1	0.9	0.9	0.8	0.5	1.2
Total Solids		435				355		333		315		351		319		305	303	327	316	340	336
Total Volatile Solids		108				49		76		47		117		44		27	36	69.3	54.7	82.7	69.3
Suspended Solids		12.0				12.4		12.0		6.8		2.0		4.4		5.2	2.8	4.8	5.2	6.4	6.0
Volatile Susp. Solids		7.2				12.0		11.6		6.4		1.6		4.0		4.8	2.4	3.6	4.0	4.8	4.8
Total Kjeldahl-N		2.4												1.5							
Ammonia-N		.35																			
Nitrate-N	13.5	14.0		13.2			14.1		14.0		13.4		13.2	13.3		12.5	12.2	12.2	12.0	12.1	12.0
Temperature, °C														13							
pH														7.8							
Turbidity		4.0												2.5		2.8	2.5	2.3	2.0	3.1	3.5

(continued)

TABLE F-3 (continued)

Date	Wednesday 11/16								Thursday 11/17				
Time	6:30	p.m. 8:00	11:00	1:00	3:00	6:00	7:30	a.m.	9:00	10:00	11:00	12:00	2:00
ΔT After Shock, hrs	10.0								1.0	2.0	3.0	4.0	6.0
COD-Total	35.4						27.6	SHOCK LOADING @ 8:00 a.m.	31.5	35.4	35.7	47.6	43.3
COD-Soluble	27.6						15.8		27.6	27.6	19.7	19.7	23.6
BOD-Total	3.5						3.1		2.8	4.2	4.4	4.2	5.1
BOD-N Suppressed	1.0						1.2		0.9	2.0	1.5	2.3	2.4
Total Solids	328						327		327	316	308	292	292
Total Volatile Solids	70.7						57.3		60.0	68.0	56.0	66.7	21.0
Suspended Solids	11.2						3.2		5.2	2.8	5.6	6.8	7.2
Volatile Susp. Solids	8.0						3.2		5.2	2.8	5.6	6.4	6.4
Total Kjeldahl-N							1.3						2.0
Ammonia-N		0.6	0.5	0.6	0.7	0.4	0.3		0.3	0.8	0.8	1.3	1.8
Nitrate-N	12.0	11.5	11.2	11.1	10.8	10.3	10.0		10.0	10.0	9.8	9.4	9.0
Temperature, °C							14						
pH							7.2						
Turbidity	3.7						2.4		3.7	2.7	3.8	3.8	4.6

Date	Thursday 11/17					Friday 11/18						
Time	4:00	6:00	p.m. 7:00	9:00	10:30	12:00	a.m. 1:30	3:00	5:00	6:30	7:30	8:00
ΔT After Shock, hrs	8.0	10.0	11.0	13.0	14.5	16.0	17.5	19.0	21.0	22.5		
COD-Total	43.7	35.4									35.4	
COD-Soluble	31.5	31.5									31.5	
BOD-Total	5.4	6.0									3.7	
BOD-N Suppressed	2.5	2.2									1.7	
Total Solids	288	295										28.3
Total Volatile Solids												44.0
Suspended Solids	6.8	5.6										1.6
Volatile Susp. Solids	6.0	5.2										1.2
Total Kjeldahl-N											1.0	
Ammonia-N	1.5	1.7	2.0	2.0	1.8	2.5	2.4	2.1	1.8	1.8	2.0	
Nitrate-N	8.8	8.8	8.2	8.1	8.1	8.1	8.6	7.8	7.7	7.3	7.0	
Temperature, °C												
pH											14.2	
Turbidity	4.7	4.5									14.2	

TABLE F-4

MEDFIELD - PHASE IIIB (shock loading)

DISSOLVED OXYGEN (mg/l)

Aerator Settings

Date	#1	#2	#3	#4
Sun 11-13	High	High	Low	Low
Mon 11-14	High	High	Low	Low
Tue 11-15	High	Low	Low	Low
Wed 11-16	High	High	Low	Low
Thur 11-17	High	High	Low	Low

Date						Monday 11/14/77													
Time	a.m. 7:20		9:00	9:30	10:00	10:35	11:00	11:30	noon 12:00	12:30	p.m. 1:00	1:30	2:00	2:30	3:00	3:30	4:00	5:00	6:00
ΔT After Shock	Before	SHOCK @ 8:00 a.m.	1.0	1.5	2.0	2.5+	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	9.0	10.0
Basin # 1 (H)	6.8		2.4	1.5	1.5	3.6	3.3	3.2	3.9	3.9	2.7	1.9	2.4	2.8	3.4	2.3	3.3	3.7	4.0
# 2 (H)	7.6		6.3	5.8	5.5	5.7	5.3	5.3	5.5	5.6	5.3	5.3	5.7	5.4	5.3	4.8	5.3	5.5	5.7
# 3 (L)	6.9		6.3	5.7	5.3	5.4	5.1	5.2	5.3	5.2	5.2	5.2	5.1	4.9	4.8	4.4	4.5	5.0	5.2
# 4 (L)	6.6		6.1	5.6	5.1	4.9	4.7	4.8	5.3	4.8	4.9	4.7	4.7	4.6	4.3	4.0	4.0	4.6	4.8
Clarifier	5.4		5.3	5.3	5.2	5.6	5.3	4.4	4.4	4.1	4.2	4.2	4.1	4.1	4.0	3.5	3.7	3.7	3.7

Date						Tuesday 11/15/77														
Time	a.m. 7:20		9:00	9:30	10:00	10:30	11:00	11:30	noon 12:00	12:30	p.m. 1:00	1:30	2:00	2:30	3:00	3:30	4:00	4:30	5:30	6:30
ΔT After Shock		SHOCK @ 8:30 a.m.	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	9.0	10.0
Basin # 1 (H)	6.9		2.7	1.9	2.2	3.2	3.7	3.6	3.2	2.9	2.7	2.5	2.6	2.2	1.9	1.9	1.8	1.8	2.2	2.4
# 2 (L)	6.1		3.3	1.2	0.5	0.3	0.5	0.4	0.6	0.3	0.5	0.3	0.4	0.5	0.2	1.1	1.0	0.5	1.6	1.8
# 3 (L)	5.6		3.2	1.7	0.6	0.2	0.3	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.2	0.4	0.5	0.7	0.8
# 4 (L)	5.5		3.4	1.8	0.7	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.3	0.3	0.4	0.7	0.7
Clarifier	5.0		4.7	3.8	3.1	2.5	1.7	1.1	1.0	0.5	0.2	0.3	0.2	0.1	0.1	0.2	0.4	0.4	0.5	0.5

(continued)

TABLE F-4 (continued)

Date	Wednesday 11/16/77																
Time	a.m. 7:30		9:00	9:30	10:00	10:30	11:00	11:30	noon 12:00	12:30	p.m. 1:00	1:30	2:00	2:30	3:00	3:30	4:30	p.m. 5:30
ΔT After Shock		SHOCK @ 8:30 a.m.	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
Basin # 1 (H)	7.4		1.6	1.5	1.5	2.9	3.3	3.1	3.0	2.8	2.5	2.1	2.2	2.3	1.8	1.8		
# 2 (H)	7.1		4.5	4.0	3.9	3.3	3.5	3.6	3.6	3.5	3.9	3.8	4.0	3.8	3.6	4.2		
# 3 (I)	5.7		4.3	4.3	3.5	3.1	3.0	2.9	2.9	3.0	3.1	3.2	3.3	3.0	3.0	3.1		
# 4 (I)	5.1		3.8	3.4	3.1	2.9	2.6	2.5	2.5	2.4	2.5	2.8	2.7	2.6	2.5	2.6		
Clarifier	3.7		3.3	3.1	3.5	3.2	2.3	1.8	2.3	2.0	1.5	1.2	1.2	1.2	1.1	1.2		

Date	Thursday 11/17/77																Friday 11/18/77	
Time	a.m. 7:30		8:00	9:00	9:30	10:00	10:30	11:00	11:30	noon 12:00	p.m 1:00	1:30	2:30	3:30	4:30	5:30	a.m. 7:45	9:45
ΔT After Shock		SHOCK @ 8:00 a.m.	0	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	5.5	6.5	7.5	8.5	9.5	24-	26-
Basin # 1 (H)	6.9		5.0	1.3	1.2	1.1	1.2	1.9	2.3	2.4	2.2	2.2	2.0	1.9	1.3	1.5	5.0	5.8
# 2 (H)	6.5		6.0	2.5	1.9	1.5	1.6	2.1	1.1	1.4	1.2	2.0	2.2	2.7	2.6	2.7	4.2	5.0
# 3 (I)	4.8		4.8	3.0	0.9	0.6	0.7	0.5	0.6	0.6	0.5	0.7	1.1	1.1	1.4	1.5	3.2	3.7
# 4 (I)	3.9		3.9	2.5	0.4	0.3	0.2	0.2	0.3	0.2	0.2	0.2	0.5	0.5	0.5	0.5	2.8	3.0
Clarifier	2.0		2.0	1.9	0.6	0.4	0.3	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.5	1.0

TABLE F-5

MEDFIELD - PHASE IIIB (shock loading)

MIXED LIQUOR (mg/1)

Date	11/14			Basin #3																
	a.m.				noon	p.m.		4:00			a.m.				noon	p.m.		4:00		
Time	7:30	9:00	10:00	11:00	12:00	2:00	3:30		4:30	5:30	7:30	9:00	10:00	11:00	12:00	2:00	3:30		4:30	5:30
ΔT After Shock		1.0	2.0	3.0	4.0	6.0	7.5		8.5	9.5		1.0	2.0	3.0	4.0	6.0	7.5		8.5	9.5
Total Solids	7780	8360	8210	7970	8380			8340			8260	8340		8340		8840		7740		
Total Vol. Solids	4390	4800	4710	4550	4900			4810			4670	4870		4860		5080		4500		
Suspended Solids	7380	7970	7880	7600	7960			7940			7870	7970		7980		8420		7400		
Volatile Susp Solids	4340	4740	4640	4510	4500			4750			4590	4830		4800		5650		4410		
Alkalinity	467	422	436	428	382	394		374			417	420	420	378	432	390		338		
Settlometer																				
5 minutes #4	900	910	910	910	890	900					940	910	930	930	900	810				
10 minutes	830	840	840	750	800	790					850	750	860	840	800	620				
15 minutes	750	760	770	640	720	690					780	640	770	750	700	550				
20 minutes #1	680	700	690	580	650	610					700	570	700	670	610	490				
25 minutes	620	630	620	530	580	550					630	520	630	600	550	450				
30 minutes	570	580	570	500	540	510					570	480	580	550	510	420				
45 minutes	460	470	460	430	440	430					470	400	470	460	430	370				
60 minutes	410	420	400	390	390	380					410	360	410	400	390	340				
Settling Column (#4), (mm settled)					p.m. 1:00															
5 minutes					41.3															
10 minutes					111.1															
15 minutes					181.0															
20 minutes					254.0															
25 minutes					330.2															
30 minutes					403.2															
45 minutes					627.1															
60 minutes					831.9															
D.O. uptake mg/1/hr	8.3	8.4	8.1	8.1	8.4	8.5	8.4		8.8	7.2	8.7	22.9	20.7	23.3	21.9	20.8	21.1		20.5	19.8

(continued)

TABLE F-5 (continued)

		Basin #3							Basin #1						
Date		Tuesday 11/15/77													
Time		a.m. 7:30	9:30	10:30	11:30	p.m. 12:30	2:30	4:30	a.m. 7:30	9:30	10:30	11:30	p.m. 12:30	2:30	4:30
ΔT After Shock			1.0	2.0	3.0	4.0	6.0	8.0		1.0	2.0	3.0	4.0	6.0	8.0
Total Solids			8360	8260	8410	7970	7880	7830	8490		8140	9120	8400	7700	8500
Total Vol. Solids			5080	5000	5100	4540	4440	4500	5030		5060	5480	4810	4410	4950
Suspended Solids			8000	7920	8070	7550	7420	7490	8130		7820	8800	8090	7360	8170
Volatile Susp. Solids			4970	4850	4960	4460	4380	4410	4940		5010	5430	4710	4350	4900
Alkalinity		320	252	302	294	298	282	298	292	286	270	280	306	276	290
Settlometer															
5 minutes	Basin #4	930	920	840	920	920	910	920	750	730	770	830	890	900	890
10 minutes	&	810	800	770	830	840	810	840	620	580	670	650	740	750	800
15 minutes	Basin #1	780	700	680	770	770	710	750	550	520	590	550	620	640	730
20 minutes		700	610	620	700	690	630	670	500	470	540	490	560	570	650
25 minutes		630	550	550	640	620	570	590	460	440	490	450	510	530	580
30 minutes		570	510	500	580	560	530	550	430	400	460	420	470	490	540
45 minutes		[illegible]	430	430	470	460	440	460	390	350	400	370	400	410	440
60 minutes		420	400	390	410	400	400	410	330	320	370	340	370	370	390
Settling Column, mm settled						1:00 p.m.									
5 minutes						12.7									
10 minutes						93.7									
15 minutes						160.3									
20 minutes						231.8									
25 minutes						303.2									
30 minutes						374.7									
45 minutes						581.0									
60 minutes						774.7									
D.O. Uptake		7.7	7.6	9.8	10.1	9.6	10.1	17.5	9.1	25.0	20.3	25.8	25.2	21.3	26.8

(continued)

TABLE F-5 (continued)

	Basin #3									Basin #1								
Date	Wednesday 11/16/77																	
Time	a.m. 7:30	9:30	10:30	11:30	p.m. 12:30	2:30	4:30	5:30	6:30	a.m. 7:30	9:30	10:30	11:30	p.m. 12:30	2:30	4:30	5:30	6:30
ΔT after shock		1.0	2.0	3.0	4.0	6.0	8.0	9.0	10.0		1.0	2.0	3.0	4.0	6.0	8.0	9.0	10.0
Total Solids	8930	8770	8690	7390	7890	7380	8060		8030	8400	7860	7950	8050	8080	8070	7380		7940
Total Vol. Solids	5370	5220	5240	4420	4810	4460	4770		4780	5110	4880	4960	4750	4840	4860	4310		4690
Suspended Solids	8660	8600	8450	7020	7570	7040	7750		7740	8140	7580	7760	7720	7770	7650	7070		7640
Volatile Susp. Solids	5350	5200	5220	4340	4750	4380	4730		4740	5050	4830	4910	4690	4760	4740	4260		4640
Alkalinity	242	208	202	268	240	264	216		220	228	194	216	216	244	252	232		242
Settlometer																		
5 minutes Basins	920	900		840	890	900	880			920	840		710	720	720	850		
10 minutes #4	850	810	850	710	790	780	690			860	660	680	550	560	550	710		
15 minutes	780	720	750	610	690	670	580			770	560	570	480	490	470	610		
20 minutes &	700	650	650	540	610	590	520			710	500	500	430	450	430	540		
25 minutes	630	590	590	490	540	530	480			640	450	450	390	400	400	500		
30 minutes #1	580	530	540	450	500	490	440			590	420	420	370	380	370	470		
45 minutes	470	440	440	390	410	410	390			480	360	350	330	340	330	400		
60 minutes	420	390	390	350	370	370	350			430	320	320	300	300	310	360		
Settling Column, mm settled					p.m. 1:00													
5 minutes					44.5													
10 minutes					123.8													
15 minutes					200.0													
20 minutes					282.6													
25 minutes					358.8													
30 minutes					450.9													
45 minutes					704.6													
60 minutes					923.9													
D.O. Uptake	12.1	10.8	14.1	13.3	13.7	12.8	13.0	11.4		12.5	24.2	25.3	24.8	23.0	24.6	28.3	23.1	
Settlometer Supernatant Turbidity, Ntu	3.2	5.4	4.4	6.7	12.0	9.0	6.5			5.3	17	12	12	13	8	8.5		

(continued)

TABLE F-5 (continued)

	Basin #3									Basin #1								
Date	Thursday 11/17/77								Friday 11/18/77									
Time	a.m. 7:30	9:00	10:00	11:00	noon 12:00	p.m. 2:00	4:00	6:00	a.m. 8:00	a.m. 7:30	9:00	10:00	11:00	noon 12:00	p.m. 2:00	4:00	p.m. 6:00	a.m. 8:00
ΔT After Shock		1.0	2.0	3.0	4.0	6.0	8.0	10.0	24.0		1.0	2.0	3.0	4.0	6.0	8.0	10.0	24.0
Total Solids	6830	5700	8440	8740		7600	7990	8210	8310	8210	7710	8600	7270	8450	8270	8320	8080	8080
Total Vol. Solids	4050	3400	5140	5310		4460	4760	4800	4890	4840	4900	5310	4370	5120	4920	4950	4790	4680
Suspended Solids	6540	5420	8140	8440		7290	7740	7960	8100	7930	7420	8310	6980	8170	8000	8070	7840	7850
Volatile Susp. Solids	4210	3370	5090	5250		4390	4750	4800	4890	4820	4640	5160	4310	5010	4890	4930	4750	4650
Alkalinity	234	228	204	206	224					226	240	250	260	234				
Settlometer																		
5 minutes	900	930	920	860	870	860	920		950	900	900	900	850	890	900	920		940
10 minutes	780	850	850	730	740	690	810		890	790	770	780	730	760	770	810		880
15 minutes	680	770	770	610	640	580	710		830	700	680	670	650	650	670	710		810
20 minutes	600	700	700	550	560	520	630		770	620	600	600	570	560	590	630		740
25 minutes	550	620	630	500	510	480	570		710	550	550	540	520	510	530	570		680
30 minutes	510	570	570	470	480	440	530		650	500	500	500	480	470	490	530		620
45 minutes	440	480	460	410	410	390	420		530	420	420	420	410	410	420	440		500
60 minutes	400	430	410	380	380	360	380		450	380	380	390	380	370	380	390		430
Settling Column					p.m. 1:00													
5 minutes					25.4													
10 minutes					104.8													
15 minutes					181.0													
20 minutes					260.4													
25 minutes					336.6													
30 minutes					415.9													
45 minutes					644.5													
60 minutes					847.7													
D.O. Uptake	15.0	15.4	13.5	19.2	17.2	18.5	19.2	18.4	10.4	16.3	38.4	24.2	32.5	40.4	46.9	32.7		13.8
Settlometer Supernatant Turbidity, Ntu	4.5	3.8	5.0		Basin #4	8.5	8.5			3.5	23			Basin #1	8.5	8.5		

TABLE F-6

MEDFIELD - PHASE IIIB

SECONDARY SLUDGE (mg/l)

Date	11/14*	11/15	11/16	11/17	11/18
Day	Mon	Tue	Wed	Thur	Fri
Total Solids	11980	6350	10000	14090	8430
Total Vol. Solids	6830	3600	5896	8510	4940
Suspended Solids	11520	5740	9720	13360	8190
Volatile Susp. Solids	6760	3320	5830	8440	4930
Flow Rate, mgd	.406	.462	.435	.412	.494
Capillary Suction Test	7.2	7.1	6.1	6.4	6.6

*Samples collected at 7:30 a.m.

TABLE F-7

MEDFIELD - PHASE IIIB (shock loading)

MICROBIOLOGICAL INDICES

Mixed Liquor Basin #1

Date		Monday 11/14/77				Tuesday 11/15				Wednesday 11/16			Thursday 11/17			Friday 11/18
Time		7:30	9:00	11:00	4:00	7:30	9:30	11:30	4:30	7:30	9:30	2:30	7:30	9:00	12:00	8:00
No. of Individuals	(N)	71	39	65	55	74	39	42	45	41	31	38	66	49	38	39
No. of Species	(S)	5	5	7	7	7	3	4	5	5	3	4	4	3	3	4
Diversity Index	(H)	1.49	1.22	1.94	1.40	1.02	0.76	0.80	0.98	1.26	0.75	0.96	1.21	0.65	0.87	0.75

Secondary Effluent

Date		Monday 11/14/77				Tuesday 11/15			Wednesday 11/16			Thursday 11/17		Friday 11/18
Time		7:20	11:00	2:00	4:00	7:30	11:30	4:30	7:30	11:30	2:30	7:30	12:00	8:00
No. of Individuals	(N)	19	24	32	33	18	21	19	30	25	27	5	8	21
No. of Species	(S)	4	4	6	6	3	4	4	6	4	4	3	3	5
Diversity Index	(H)	1.80	1.74	1.91	1.54	1.22	1.64	1.06	1.64	1.29	1.20	1.37	1.06	1.84

APPENDIX G

TABLE G-1

MARLBOROUGH - PHASE I

INFLUENT (mg/l)

Date	*4/17	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	5/1	5/2	5/3	5/4	5/5	5/6	5/7
Day	Mon	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Mon	Tues	Wed	Thur	Fri	Sat	Sun
Flow Rate, cu m/sec	0.13	0.13	0.12	0.12	0.14	0.14	0.14	0.13	0.13	0.12	0.12	0.11	0.11	0.10	0.10	0.10	0.11	0.11
mgd	(2.9)	(2.9)	(2.8)	(2.8)	(3.2)	(3.1)	(3.2)	(3.0)	(3.0)	(2.7)	(2.8)	(2.6)	(2.5)	(2.3)	(2.3)	(2.3)	(2.4)	(2.4)
COD-Total	230	296	188	297	286	259	180	345	319	408	337	373	462	344	372	325	410	267
COD-Soluble	70	109	89.8	73.4	159	74.5	66.7	83.4	114	102	89.1	100	55.3	106	68	103	79.7	71.7
BOD-Total	45	111	115	185	147	46	60	106	100	153		112	141	142	147	144	155	129
BOD-N Suppressed	32	53	87	121	129	36	45	84	53	123		85	106	136	132	54	107	90
Total Solids	340	528	584	2070	350	532	320	876	444	432	1022	834	280	1912	678	672	524	484
Total Volatile Solids	192	278	330	1840	182	360	118	686	244	182	746	222	4	1600	428	458	316	232
Suspended Solids	71	67	358	1690	57	88	40	140	128	122	104	253	264	132	74	94	142	156
Volatile Susp. Solids	68	64	312	1630	55	78	14	130	102	118	90	237	238	128	10	66	104	146
Total Kjeldahl-N	24.6	19.3	21.6	23.0	20.4	16.0	17.1	27	19.9	28.8	24.6	23.2	26.3	27.7	30.5			25.8
Ammonia-N	12	15	15	15	16	13	12	16	16	20	18	20	16	18	19	12	19	20
Nitrate-N	1.4	0.8	1.0	0.9	1.1	1.0	0.9	1.1	1.2	1.7	1.1	0.9	0.4	0.8	0.9	0.8	0.9	0.9
Total Phosphorus	2.1	7.7	7.8	5.9	6.5	5.7	2.7	5.7	3.8	4.9	7.1	7.3	5.8	5.5		10.0	3.3	3.8
Grease			237								121			141		124		
Alkalinity		100	90	103	118	97	98	99	74	80	110	126	130	131	129	134	148	129
pH		6.2	6.3	6.4	6.5	6.5	7.1	7.1	6.6	7.1	6.6	6.8	6.9	7.0	6.9	7.2	7.2	7.0
Temperature, °C		8.0	8.1	9.5	8.9	9.0	10.0	9.8	9.9	9.9	9.9	10.8	10.8	10.8	11.5	11.0	12.0	13.2

*Grab Sample

TABLE G-2

MARLBOROUGH - PHASE I

PRIMARY EFFLUENT (mg/1)

Date	*4/17	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	5/1	5/2	5/3	5/4	5/5	5/6	5/7
Day	Mon	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Mon	Tues	Wed	Thur	Fri	Sat	Sun
COD-Total	284	125	180	182	218	157	126	196	193	204	194	627	221	434	472	274	120	247
COD-Soluble	73.9	148	78.1	73.4	51.6	50.9	39.2	66.7	55.1	74.5	77.5	100	87	184	64	63.5	47.8	67.7
BOD-Total	101	172	60	84	94	39	27	48	71	82		57	77	154	285	147	52	147
BOD-N Suppressed	63	110	39	50	65	30		25	44	53		46	51	151	180	142	31	83
Total Solids	436	582	314	360	316	304	310	328	388	378	388	898	488	610	962	614	386	503
Total Volatile Solids	186	262	100	160	130		122	140	156	166	156	232	174	254	394	264	170	216
Suspended Solids	104	53	70	78	48	46	46	58	56	66	44	84	92	210	470	220	54	116
Volatile Susp. Solids	88	40	52	64	46	37	34	46	60	60	40	80	80	154	176	126	40	80
Total Kjeldahl-N		37.2	24.9	22.4	23.5	17.4	14.0	20.2	16.5	20.5	31.1	29.1	28.6	45.0	44.8			27.2
Ammonia-N	18	20	10	17	14	15	12	13	14	15	16	18	21	36	17	16	15	15
Nitrate-N	0.5	2.4	1.9	0.7	0.8	0.9	0.8	0.8	0.7	1.2	1.5	0.8	0.8	0.7	0.8	0.7	0.8	0.8
Total Phosphorous	6.4	14.6	3.1	5.2	5.6	4.0	1.6	6.0	5.4	5.2	4.2	5.5	4.6	6.4		5.3		4.5
Alkalinity	105	98	74	128	130	128	73	105	118	118	94	183	185	223	203	192	129	164
pH	6.3	6.3	6.3	6.7	6.4	6.7	6.8	6.8	6.9	7.1	6.9	7.2	7.6	7.2	7.0	7.3	6.9	6.8
** Temperature, ^{o}C			9	9	9	9	9	9	9	9	10	10	10	12	11	11	11	12
** Dissolved Oxygen-Top		1.3	8.6	0.4	3.5	5.3	1.2	1.1	1.1	3.9	2.2	2.9	1.4	2.9	1.6	0.6	0.5	0.4
** Dissolved Oxygen-Bottom												0.5		0.4		0.4	0.2	0.1
Grease			17.8								287			51.6		329		

* Grab sample ** Measured in the primary clarifier

TABLE G-3

MARLBOROUGH - PHASE I

SECONDARY EFFLUENT (mg/l)

Date	*4/17	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	5/1	5/2	5/3	5/4	5/5	5/6	5/7
Day	Mon	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Mon	Tues	Wed	Thur	Fri	Sat	Sun
COD-Total	73.9	81.7	78.1	27.0	43.7	58.8	82.4	43.1	47.2	47.1	58.1	34.6	55.3	62.5	72	55.6	39.8	35.9
COD-Soluble	50.6	62.3	50.8	19.3	31.7	47.1	54.9	35.3	35.4	39.2	42.6	26.9	27.7	31.3	40	31.7	27.9	19.9
BOD-Total	15.0	19.1	8.1	13.8	15.0	11.2	3.3	6.7	9.0	8.1		16.5	5.1	19.7	15.6	12.4	4.3	12.6
BOD-N Suppressed	8.4	9.5	5.2	6.2	7.6	2.4	1.1		1.2	2.7		< 1	< 1	6.0	7.2	3.9	1.9	2.7
Total Solids	278	354	372	310	284	348	270	260	324	302	348	758	364	372	388	370	356	388
Total Volatile Solids	30	72	110	46	76	132	68	76	70	124	84	108	34	224	84	64	132	122
Suspended Solids	16	10	19	10	2	12	7	1	7	9	9	7	10	8	13	17	12	11
Volatile Susp. Solids	13	8	14	8	1	8	2	1	6	6	8	5	9	6	11	12	8	10
Total Kjeldahl-N	15.9	16.8	15.0	14.7	15.1	12.7	9.7	10.2	13.7	13.3	16.4	16.2	14.8	27.3	20.7			16.8
Ammonia-N	12	13	12	11	11	15	12	10	10	14	18	13	13	21	16	13	13	15
Nitrate-N	1.0	3.5	3.7	3.5	3.4	1.0	3.1	3.4	2.9	3.8	3.4	4.0	3.6	3.5	3.2	3.7	1.3	5.0
Total Phosphorous	1.5	1.8	1.8	0.3	0.7	0.8	0.7	0.7	0.6	0.5	1.7	0.7	0.5	0.8		0.2	1.3	1.5
Alkalinity	78	73	73	68	67	70	55	42	58	71	97	119	120	145	133	130	114	92
pH	6.4	6.3	6.3	6.3	6.5	6.8	6.8	6.7	6.9	7.0	7.0	6.9	7.1	7.3	7.0	7.2	7.1	6.9
** Temperature, ^{o}C			10	10	10	10	10	10	10	10	10	11	11	11	12	12	12	13
** Dissolved Oxygen		3.6	2.1	3.5	4.8	7.6	3.9	5.7	5.6	4.9	4.8	4.5	5.5	5.3	0.4	4.2	4.1	5.3
Grease										65.4	29.1			23.1		37.9		

*Grab Sample ** Measured in the first stage final clarifier

TABLE G-4

MARLBOROUGH - PHASE I

FINAL EFFLUENT (mg/l)

Date	*4/17	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	5/1	5/2	5/3	5/4	5/5	5/6	5/7
Day	Mon	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Mon	Tues	Wed	Thur	Fri	Sat	Sun
COD-Total	42.8	46.7	43.0	43.5	47.6	43.1	39.2	35.3	23.6	47.1	42.6	26.9	35.6	35.2	44	31.7	35.9	35.9
COD-Soluble	23.3	46.7	43.0	34.8	43.7	31.4	27.5	31.4	19.7	27.5	34.9	23.1	15.8	31.3	32	27.8	23.9	23.5
BOD-Total	5.4	1.7	4.4	2.6	2.1	1.0	2.5	1.4	1.9	2.6		7.8	0.5	1.1	1.1	1.1	6.1	9.9
BOD-N Suppressed	1.5	1.5	1.7	1.4	0.9	1.0	1.0	0.5	0.4	0.7				0.2	0.2	0.8	0.5	0.1
Total Solids	374	448	474	412	378	368	410	388	400	340	516	776	462	506	542	544	486	510
Total Volatile Solids	62	106	182	166	100	42	128	96	92	86	80	84	106	106	186	210	190	228
Suspended Solids	35	3	18	8	5	1	5	1	2	3	3	3	11	2	5	11	10	2
Volatile Susp. Solids	21	2	12	7	4	1	2	1	2	2	2	2	10	1	3	6	2	1
Total Kjeldahl-N	2.1	2.1	2.4	1.4	1.8	1.0	1.4	0.8	1.0	1.1	1.5	1.4	1.4	2.2	1.8			1.8
Ammonia-N	0.6	0.3	0.5	0.6	1.3	<.5	0.1	0.2	0.7	0.3	0.3	0.4	0.1	0.2	0.2	0.4	1.6	1.0
Nitrate-N	16	19	19	17	17	18	17	16	17	17	19	16	15	19	26	24	18	22
Total Phosphorous	1.5	2.0	1.5	0.5	0.7	0.4	0.3	0.4	0.2	0.2	0.6	0.4	0.3	0.3		0.2	0.1	0.1
Alkalinity	45	26	29	41	30	32	52	42	39	≠91	≠148	46	57	58	56	58	52	40
pH	6.6	6.1	6.2	6.3	6.5	6.7	7.3	7.0	7.0	7.5	7.4	6.6	7.2	7.0	6.7	6.9	7.0	6.9
** Temperature, °C			10	9	10	10	10	10	10	10	10	10	10	10	11	11	11	12
** Dissolved Oxygen		7.0	9.1	6.3	5.5	4.8	5.4	6.8	6.5	7.0	5.8	6.6	6.3	6.5	0.8	5.3	4.5	6.6
Grease			4.4								8.9			25.4				

≠ Adding alkaline waste to second stage * Grab sample ** Measured in the second stage final clarifier

TABLE G-5

MARLBOROUGH - PHASE I

MIXED LIQUOR (mg/l)

Date	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	5/2	5/3	5/4	5/5	5/6	5/7
Day	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Tues	Wed	Thur	Fri	Sat	Sun
Total Solids	2140	2880	2580	2230	1890	2470	1320	1390	1400	1430	1600	1310	1640	1910	1830	1610	1300
Total Volatile Solids	1450	1980	1750	1430	1250	1610	865	830	880	870	1020	770	960	1160	1170	940	810
Suspended Solids	1900	2590	2290	1980	1650	2170	1060	1100	1050	1100	1270	930	1270	1480	1430	1130	940
Volatile Suspended Solids	1360	1920	1690	1360	1200	1530	820	790	800	680	950	640	900	1030	1000	860	680
pH	6.4	6.4	6.3	6.4	6.5	6.7	6.7	6.8	6.9	6.9	6.9	6.8	7.1	7.0	7.1	7.1	7.0
Temperature, ^{o}C	9	9	10	10	10	10	9	10	10	10	11	11	12	12	11	12	12
Alkalinity	123	125	127	105	127	125	95	92	91	103	104	155	171	204	166	178	155
D.O. Uptake, mg/l-hr	19.7	30	30.2	17.6	27.2	23.8	16.3	15.5	18.5	13.6	12.5	14.8	12.8	28.2	15.5	19.3	16.2
Dissolved Oxygen	6.7	7.7	7.4	7.9	4.0	7.5	8.4	8.1	8.0	7.5	8.0	8.6	8.5	4.1	7.6	7.3	9.1
Total Kjeldahl-N			202		128	143	115	89	98	87			111			123	115
Ammonia-N	14	11	15	11	13	14	14	13	12	13	17	12	20	27	15	17	17
Nitrate-N	0.8	0.9	0.8	0.9	1.0	0.9	0.7	0.9	1.0	1.1	0.9	0.9	0.7	0.9	0.8	0.6	1.0
Settlometer (Avg. 3 values)																	
5 minutes	350	385	325	210	330	345	245	195	190	195	185	145	155	180	230	215	185
10 minutes	265	295	255	165	260	260	190	155	150	150	145	115	120	150	185	175	140
15 minutes	215	265	220	145	230	235	170	145	135	140	135	110	110	140	175	160	125
20 minutes	190	245	195	135	210	210	155	140	130	135	130	110	105	135	165	150	125
25 minutes	180	235	180	130	200	200	150	135	125	125	130	105	100	130	160	145	120
30 minutes	175	220	175	130	190	195	145	130	125	125	130	105	95	125	160	140	120
40 minutes	165	210	165	120	185	190	140	125	125	125	125	100	90	120	155	130	115
50 minutes	160	195	160	115	175	180	135	115	120	125	125	95	90	115	150	130	115
60 minutes	160	190	155	115	165	175	135	115	120	120	120	95	90	115	150	130	115

TABLE G-6

MARLBOROUGH - PHASE I

MIXED LIQUOR - SECOND STAGE - FIRST COMPARTMENT (mg/l)

Date	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	5/2	5/3	5/4	5/5	5/6	5/7
Day	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Tues	Wed	Thur	Fri	Sat	Sun
Total Solids	3820	3480	3940	3560	3270	4060	2780	3900	4130	3750	3890	4100	4070	3980	4030	3970	3950
Total Volatile Solids	2260	2050	2350	2120	1950	2440	1700	2340	2360	2190	2190	2470	2390	2300	2420	2190	2280
Suspended Solids	3500	3100	3520	3190	2930	3630	2510	3500	3610	3290	3350	3670	3600	3520	3580	2510	3500
Volatile Susp. Solids	2140	1970	2260	2050	1900	2330	1670	2280	2240	2030	2090	2390	2290	2200	2300	2090	2100
pH	6.5	6.3	6.2	6.4	6.6	7.0	7.0	6.9	7.5	7.6	7.4	6.8	6.8	7.0	7.7	6.8	6.8
Temperature, °C	9	9	9	10	10	10	10	10	10	11	11	10	11	11	11	11	12
Alkalinity	118	139	144	142	145	215	167	138	205	279	332	181	194	231	169	173	174
D.O. Uptake, mg/l-hr	37.8	60.0	24.0	56.8	60.0	40.6	15.1	37.2	60.0	19.6	35.1	12.6	57.6	65.5	60.0	66.7	66.7
Dissolved Oxygen	1.1	1.6	1.0	0.6	0.7	0.7	0.7	0.8	0.8	0.7	0.7	0.6	0.7	0.5	0.5	0.5	0.3
Total Kjeldahl-N					148	185	174	174	174	193			215			182	218
Ammonia-N	2.4	0.9	1.5	3.5	6.5	2.6	3.1	2.0	1.1	3.2	0.9	1.4	0.6	1.0	0.3	3.8	4.2
Nitrate-N		12.5	10	12.5	9.5	6.5	6.0	8.0	13	9.8	15.5	13.5	14.5	17.5	18	17	9.5

TABLE G-7

MARLBOROUGH - PHASE I

MIXED LIQUOR - SECOND STAGE - LAST COMPARTMENT (mg/l)

Date	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	5/2	5/3	5/4	5/5	5/6	5/7
Day	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Tues	Wed	Thur	Fri	Sat	Sun
Total Solids	3930	4120	4210	4000	3830	3750	3970	4060	4280	4100	4150	4170	2750	4490	3190	4050	4060
Total Volatile Solids	2440	2470	2480	2340	2290	2240	2380	2430	2460	2400	2310	2480	1570	2680	1900	2260	2470
Suspended Solids	3600	3720	3770	3600	3500	3350	3580	3630	3790	3560	3580	3700	2320	4010	2750	3580	3610
Volatile Susp. Solids	2370	2360	2380	2160	2170	2170	2280	2310	2380	2220	2210	2410	1520	2540	1680	2130	2280
pH	6.8	6.3	6.2	6.8	6.5	7.0	6.9	6.8	7.4	7.5	7.2	6.8	6.8	6.8	6.7	6.7	6.7
Temperature, ^{o}C	9	9	9	10	10	10	10	10	10	11	11	10	11	11	11	11	12
Alkalinity, $CaCO_3$	136	140	169	152	147	207	180	137	218	266	282	183	202	193	193	159	159
D.O. Uptake, mg/l-hr	15.7	17.3	16.4	15.3	14.4	19.1	14.3	14.2	15.9	28.4	11.5	14.3	11.9	13.2	10.0	13.2	14.1
Dissolved Oxygen	8.5	9.2	8.6	8.1	6.5	8.7	8.4	8.4	8.6	7.8	8.3	8.7	7.7	5.5	7.8	7.5	8.5
Total Kjeldahl-N					145	174	162	176	171	204				251		120	227
Ammonia-N	1.7	0.4	1.6	1.5	2.7	4.8	2.9	2.1	1.3	1.6	0.6	0.7	0.8	1.1	0.3	1.7	2.4
Nitrate-N		15	12	15	14	4.9	7.0	10	14	13	17	15	15.5	27	21	20	12
Settlometer																	
5 minutes	480	460	480	480	450	450	490	470	500	470	420	480	450	520	490	420	450
10 minutes	380	400	380	370	350	350	380	370	350	360	340	360	365	410	390	330	350
15 minutes	330	300	330	300	300	300	330	310	330	300	290	330	320	360	380	290	300
20 minutes	300	280	300	290	270	300	300	280	300	280	270	290	285	320	310	270	260
25 minutes	280	260	280	270	260	270	280	270	270	260	250	270	270	295	285	250	240
30 minutes	260	250	260	260	250	250	270	250	260	250	240	250	260	280	270	240	230
40 minutes	260	240	250	250	230	240	250	235	240	240	230	230	240	250	250	220	220
50 minutes	250	230	230	230	210	220	250	220	230	220	220	220	230	235	240	210	220
60 minutes	240	220	230	220	200	220	250	210	220	215	210	210	225	230	235	210	210

TABLE G-8

MARLBOROUGH - PHASE I

RETURNED AND COMBINED SLUDGES (mg/l)

Date	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	5/1	5/2	5/3	5/4	5/5	5/6	5/7
Sludge Returned to First Stage Aeration																			
Total Solids	4400	4860	5350	4890	7810	5370	3720	3410	3450	2230	3290			1840	2090	2360	1220	3080	2530
Total Volatile Solids	3100	3500	3710	3370	6770	3590	2520	2340	2340	1540	2230			1080	1250	1480	810	2070	1720
Suspended Solids		4330	4970	4590	7210	4960	3410	3090	2920	1780	2940			1420	1740	1840	960	2690	2070
Volatile Susp. Solids		3350	3600	3280	6490	3440	2400	2240	2220	1510	2160			950	1190	1300	770	1910	1480
Total Kjeldahl-N				325	766	300	274	190		204	258			165				171	182
Ammonia-N	1.4	15.5	8.4	18	17	20	17	11	12	13	13			16	30	22	13	19	20
Nitrate-N	13.5	0.9	1.2	0.7	0.9	1.0	2.0	1.0	1.0	1.8	0.8			0.8	10.8	1.2	0.8	0.8	0.9
Capillary Suction Time, sec	38.4	26.6	15.2	13.0		14.7	17.3	9.0	8.4	9.2	8.6			11.2	8.1	7.7	11.4	8.1	9.7
Return Rate, cu m/sec	0.06	0.06	0.07	0.06	0.06	0.05	0.05	0.06	0.05	0.05	0.05			0.07	0.07	0.08	0.08	0.07	0.07
mgd	(1.4)	(1.4)	(1.5)	(1.4)	(1.4)	(1.2)	(1.2)	(1.3)	(1.2)	(1.2)	(1.1)			(1.6)	(1.5)	(1.7)	(1.7)	(1.6)	(1.6)
Sludge Returned to Second Stage Aeration																			
Total Solids	5680	6270	6240	6820	6330	5860	5430	6020	6380	5900	6350			6290	6290	6180	2600	5500	6400
Total Volatile Solids	3380	3860	3780	4080	3850	3470	3220	3680	3740	3390	3660			3710	3720	3580	1590	3300	3870
Suspended Solids		5890	5880	6430	5800	5440	4880	5550	5620	5360	5830			5770	5820	5680	2260	5050	5940
Volatile Susp. Solids		3790	3700	3970	3650	3360	3030	3570	3630	3390	3580			3510	3630	3500	1560	3140	3690
Total Kjeldahl-N				386	570	286	274	277		257	330			316				176	364
Ammonia-N	11	1.9	1.5	2.1	1.5	7	8	3	9	2.1	3.8			1.1	1.6	2.2	0.2	1.5	3.8
Nitrate-N	8	15	8.7	13	8.0	2.1	3.3	8.0	14	8.5	15			13	13	22	21	18	5.2
Capillary Suction Time, sec	7.6	8.1	7.2	7.7		9.0	9.8	9.5	7.4	7.3	8.1			11.7	8.2	7.3	7.7	7.7	7.9
Return Rate, cu m/sec	0.21	0.21	0.21	0.20	0.21	0.21	0.21	0.22	0.22	0.22	0.22			0.24	0.23	0.23	0.23	0.23	0.24
mgd	(4.8)	(4.8)	(4.7)	(4.6)	(4.8)	(4.9)	(4.9)	(5.0)	(5.0)	(5.1)	(5.0)			(5.5)	(5.3)	(5.3)	(5.3)	(5.3)	(5.4)

(continued)

TABLE G-8, (continued)

Date	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	5/1	5/2	5/3	5/4	5/5	5/6
Combined Primary, First and Second Stage Sludges																		
Total Solids		23930		58030	58100			57670	49460	49950				46360		57460	26270	
Total Volatile Solids		16660		33530	40180			37173	32870	32550				25470		35990	15070	
Suspended Solids		22770		52740	54530			54240	45860	46960				43440		53620	23880	
Volatile Susp. Solids		16010		30280	38050			34880	30580	30550				23650		33520	14420	
Total Kjeldahl-N		1019		2027	2027			1036	358	1697						2173	1994	
Ammonia-N		225						222	70	200				150		560	150	
Nitrate-N		8							4.9	9.0				5.5		10	0.8	
Total Phosphorous		850		1030				1240		1180				425		1360		
Capillary Suction Time, sec		268		252				468	431	386				232		499	332	
Sludge Wasted, 10^3 liters		84		105	74			110	98	83	69	73	138	95	78	96	84	
10^3 gal		(22.1)		(27.8)	(19.6)			(29.1)	(26.0)	(22.0)	(18.1)	(19.3)	(36.5)	(25.2)	(20.5)	(25.4)	(22.1)	

TABLE G-9

MARLBOROUGH - PHASE I

VACUUM FILTER (mg/l)

Date	4/18	4/20	4/21	4/24	4/25	4/26	4/27	4/28	5/1	5/2	5/4	5/5
Day	Tues	Thur	Fri	Mon	Tues	Wed	Thur	Fri	Mon	Tues	Thur	Fri
Vacuum Filter Filtrate												
COD-Total	2960	5250	4880	6270	5510	5610				4350	5700	5200
COD-Soluble	2210	3090	4050	5920	4610	4860				3580	5040	4200
BOD-Total	1260			3900	3540	3960				2590	4350	3160
BOD-N Suppressed	780			4140	2760	3630				1680	3700	2380
Total Solids	3470	8530	7870	8640	8370	8660				8210	9330	7860
Total Volatile Solids	522	2160	2270	2710	2640	2940				2080	2430	2280
Suspended Solids	627	966	716	930	1060	1180				740	1130	990
Volatile Susp. Solids	217	248	258	180	284	262				160	232	204
pH		12.1	12.1	12.0	12.1	12.0				12.3	12.2	12.1
Total Kjeldahl-N	2770	403	364		325	176				342	251	
Ammonia-N	300	600	380		290	550				340	210	
Nitrate-N						10					18	
Total Phosphorous	50	24	21								6.5	
Vacuum Filter Cake												
Total Solids, %	27.6	26.4	24.8	21.6	22.0	22.2				30.0	25.7	30.4
Total Volatile Solids,%	7.5	7.8	10.4	10.6	11.2	11.0				7.8	10.2	7.6
Quantity, kg/day		5566	3552	5820	4205	4001	3086	3151	9240	5520	5375	4105
lb/day		12270	7830	12830	9270	8820	6804	6947	20370	12170	11850	9050
Ferric Chloride, kg/day	(283)	(394)	(271)	(332)	(381)	(344)	(283)	(271)	(344)	(369)	(406)	(332)
lb/day	2126	3382	3575	3483	3092	2222	2995	2125	6956	3961	2705	3865
Lime, kg/day	4686	7455	7881	7678	6816	4899	6603	4686	15336	8733	5964	8520

APPENDIX H

TABLE H-1

MARLBOROUGH - PHASE II

SEPTAGE (mg/l)

Phase	*IIIA	*IIB
Dates	5/8 - 5/10	5/16 - 5/18
Start	Mon 8a.m.	Tues 7a.m.
Completion	Thur 8a.m.	Thur 1a.m.
Total Volume, liters	333100	375000
(gals)	(88000)	(99000)
Feed Rate, liter/day	109800	215750
(gpd)	(29000)	(57000)
% Daily Flow	1.25	2.14
COD-Total	24500	27500
BOD-Total	7410	11180
BOD-N Suppressed	5900	8450
Total Solids	16970	18940
Total Volatile Solids	12420	14450
Suspended Solids	14530	15270
Volatile Susp. Solids	10780	12160
Total Kjeldahl-N	730	640
Ammonia-N	170	100
pH	6.4	4.6
Alkalinity	830	0
Total Phosphorous	480	220
Grease	1643	3121

* Average values for samples collected during test periods

TABLE H-2

MARLBOROUGH - PHASE II

INFLUENT (mg/l)

Phase	IIA				IIB		
Date	5/8	5/9	5/10	5/11	5/15	5/16	5/18
Day	Mon	Tues	Wed	Thur	Mon	Tues	Wed
Flow Rate, cu m/sec	0.11	0.10	0.10	0.11	0.11	0.12	0.12
mgd	(2.4)	(2.3)	(2.3)	(2.4)	(2.5)	(2.7)	(2.8)
COD-Total	376	263	277	285	344	435	272
COD-Soluble	124	90.2	75.1		160	82.4	63.0
BOD-Total	136	120	130	138	177	200	138
BOD-N Suppressed	128	110	99	98	125	125	114
Total Solids		524	880	650	896		564
Total Volatile Solids		318	756	382	646		308
Suspended Solids	146	324	370	348	354		272
Volatile Susp. Solids	120	228	354	316	298		246
Total Kjeldahl-N	26.9	25.5	26.0	26.4	28.3	42.3	65.0
Ammonia-N	21	20	18	22	20	14	11
Nitrate-N	0.8	1.4	1.2	0.7	0.6	0.7	1.1
Total Phosphorous		6.3	4.6	8.5	5.5	7.3	3.3
Alkalinity	135	131	131	134	126	122	111
pH	6.9	6.9	6.9	6.8	6.8	6.7	6.6
Temperature, °C	12	12	12	12	12	12	12
Grease		124	218				209

TABLE H-3

MARLBOROUGH - PHASE II

PRIMARY EFFLUENT (mg/l)

Phase	IIA						IIB										
Date	5/8	5/9	5/10	5/10	• 5/10	5/11	5/15	5/16	5/16	5/16	5/17	5/17	5/17	5/17	5/17	5/17	5/18
Day	Mon	Tues	Wed	Wed	Wed	Thur	Mon	Tues	Tues	Tues	Wed	Wed	Wed	Wed	Wed	Wed	Thur
Composite or Grab Time	Com	Com	Com	8am	5pm	Com	Com	Com	1pm	7pm	3am	7am	1pm	5pm	9pm	Com	Com
COD-Total	327	306	296	277	443	289	420	255	332	379	371	325	488	341	413	318	191
COD-Soluble	128	82.4	83.0			58.6	96	94.1	145	160	180	153	284	158	111	82.4	63.5
BOD-Total	108	88.5	113	122		40.5	197	108	147	185	152	173	239	170	213	147	
BOD-N Suppressed	69	64.5	74			21.0	108	61.5	123	155	125	110	224	152	177	90	
Total Solids	630	620	526			526	690	516	620	530	472	460	524	438	518	508	409
Total Volatile Solids	206	388	300			182	346	268	268	250	236	228	188	156	236	250	100
Suspended Solids	170	212	216			148	284	152	132	60	112	88	142	94	140	168	108
Volatile Susp. Solids	138	122	152			98	220	112	90	48	72	78	100	68	100	132	58
Total Kjeldahl-N	32.5	34.2	33.6			45.3	40.0	41.4	65.9	37.2	14.6	25.5	66.4	26.9	25.2	29.4	28.6
Ammonia-N	21	35	28		18	18	23	24	31	28	12	15	25	14	15	17	17
Nitrate-N	0.9	1.0	0.8	1.0	1.2	1.2	0.7	0.8	0.9	1.0	1.2	1.1	0.8	0.6	0.8	0.8	0.9
Total Phosphorous		1.5	9.2			6.5	10.3	6.5	4.8	7.5	3.8	6.1	8.0	8.8	11.0	6.3	5.6
Alkalinity	192	190	194			191	177	164	230	132	111	104	199	135	111	152	153
pH	7.1	7.2	7.2			7.3	6.9	6.8	8.6	6.7	6.4	6.4	7.3	6.7	6.5	6.7	7.1
**Temperature	12	12	12			13		12								14	13
**Dissolved Oxygen-Top	0.7	4.2	1.0		1.8	0.5		0.4		2.4				1.7		2.2	1.5
Bottom	0.3	0.3	0.3			0.2		0.3								0.3	0.5
Grease		160	110													914	

** Measured in the primary clarifier.

TABLE H-4

MARLBOROUGH - PHASE II

SECONDARY EFFLUENT (mg/l)

Phase			IIA								IIB						
Date	5/8	5/9	5/10	5/10	5/10	5/11	5/15	5/16	5/16	5/16	5/17	5/17	5/17	5/17	5/17	5/17	5/18
Day	Mon	Tues	Wed	Wed	Wed	Thur	Mon	Tues	Tues	Tues	Wed	Wed	Wed	Wed	Wed	Wed	Thur
Composite or Grab Time	Com	Com	Com	8am	5pm	Com	Com	Com	1pm	7pm	3am	7am	1pm	5pm	9pm	Com	Com
COD-Total	86.3	39.2	59.3	83.0	59.3	54.7	60	43.1	78.1	58.6	62.5	35.3	90.5	59.4	64.8	51.2	43.7
COD-Soluble	70.6	35.3	51.4	67.4		43.0	52	15.7	43.0	39.1	39.0	27.5	47.5	59.3	43.5	39.4	43.7
BOD-Total	7.2	2.7	16.2	7.0		11.6	12.9	5.4	4.8	4.2	6.6	8.2	6.4	6.2	4.4	10.2	
BOD-N Suppressed	2.4	2.1	3.2	3.1		1.4	3.5	2.2	2.2	1.0	1.8	2.6	4.8	4.2	2.0	1.6	
Total Solids	376	456	352			352	360	388	342	404	364	354	328	306	358	358	346
Total Volatile Solids	134	180	160			76	112	100	80	122	106	96			34	128	18
Suspended Solids	23	16	15			24	6	11	9	7	10	19	15	11	11	10	10
Volatile Susp. Solids	3	15	9			13	4	8	6	6	7	11	11	10	6	6	8
Total Kjeldahl-N	17.6	17.2	18.2			19.3	18.8	14.3	15.0	9.5	13.0	12.9	15.4	16.5	14.3	13.4	16.6
Ammonia-N	15	16	19			12	18	19	21	17	12	11	13	12	12	13	7
Nitrate-N	5.0	4.0	4.3	1.2	1.4	5.0	4.0	2.2	1.2	1.2	0.9	1.1	0.9	1.0	1.0	2.5	3.5
Total Phosphorous		0.8	0.7			0.6	1.3	1.4	2.1	1.4	1.2	1.7	0.1	1.0	1.0	0.3	0.9
Alkalinity	110	74	134			139	103	117	117	142	93	93	93	115	98	86	87
pH	6.9	7.2	7.1			7.5	6.8	6.8	7.0	7.1	6.5	6.4	6.5	6.7	6.4	6.5	6.9
**Temperature	13	13	13			13	13	13								14	14
**Dissolved Oxygen	4.1	2.0	2.2		0.2	1.9	3.2	3.7		1.7				0.6		1.6	3.6
Grease			35.2													51.2	

**Measured in the primary clarifier.

TABLE H-5

MARLBOROUGH - PHASE II

FINAL EFFLUENT (mg/l)

Phase	IIA						IIB										
Date	5/8	5/9	5/10	5/10	5/10	5/11	5/15	5/16	5/16	5/16	5/17	5/17	5/17	5/17	5/17	5/17	5/18
Day	Mon	Tues	Wed	Wed	Wed	Thur	Mon	Tues	Tues	Tues	Wed	Wed	Wed	Wed	Wed	Wed	Thur
Composite or Grab Time	Com	Com	Com	8am	5pm	Com	Com	Com	1pm	7pm	3am	7am	1pm	5pm	9pm	Com	Com
COD-Total	47.0	47.0	39.5	43.5	39.5	31.2	44	39.2	35.2	35.2	46.9	27.5	51.2	51.2	43.3	35.4	39.7
COD-Soluble	35.3	39.2	39.5	31.6		31.2	44	35.3	35.2	27.3	35.2	23.5	35.4	43.3	39.4	23.6	43.7
BOD-Total	1.3	1.1	2.4	9.9		1.4	1.0	1.3	7.8	8.0	10.4	8.8	7.3	7.6	8.2	2.0	
BOD-N Suppressed	1.1	1.0		0.8		0.1	0.7	0.2	0.6	1.0	1.3	1.7	1.4	1.1	2.0	0.9	
Total Solids	454	500	482			504	498	494	474	442	484	566	338	372	436	500	474
Total Volatile Solids	244	224	244			100	228	200	108	154	294	232	58	72	96	200	92
Suspended Solids	18	7	30			34	8	14	16	19	16	31	38	10	21	9	17
Volatile Susp. Solids	13	7	26			22	7	11	13	10	12	18	28	8	10	6	7
Total Kjeldahl-N	2.2	2.1	1.7			1.7	2.7	3.4		2.0	2.8	2.9	3.6	2.2	3.1	2.0	2.2
Ammonia-N	0.6	0.2	0.6			0.5	0.7	1.7	0.2	0.8	0.9	0.9	0.3	0.6	0.4		0.3
Nitrate-N	20	19	20	22	21	24	21	20	19	20		18	14	15	16	18	15
Total Phosphorous		0.8	2.0			1.0	2.1	1.4	1.5	0.1	0.9	0.6	0.3	0.4	0.6	0.6	0.9
Alkalinity	37	51	50			41	30	35	47	38	51	51	52	45	42	40	40
pH	6.7	7.0	7.0			6.9	6.6	6.5	6.8	6.5	6.8	6.5	6.5	6.5	6.3	6.6	6.5
Temperature	12	13	13			13	13	12									13
Dissolved Oxygen	5.9	5.6	5.0		3.4	5.3	5.3	5.3		4.3				6.0		5.2	6.5
Grease		6.8	5.5													24.8	

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TABLE H-6

MARLBOROUGH - PHASE II

MIXED LIQUOR - FIRST STAGE (mg/l)

Phase	IIA					IIB		
Date	5/8	5/9	5/10	5/11	5/12	5/16	5/17	5/18
Day	Mon	Tues	Wed	Thur	Fri	Tues	Wed	Thur
Total Solids	1360	1760	1770	1670	1320	1570	1730	2310
Total Volatile Solids	860	1290	1180	1010	810	1080	1110	1620
Suspended Solids	970	1310	1310	1270	1270	1250	1410	1789
Volatile Susp. Solids	780	1140	920	880	760	980	1070	1400
pH	7.0	6.8	7.0	7.0	6.9	7.0	6.7	6.9
Temperature, °C	13	13	13	13	14	13	14	12
Alkalinity	143	171	149	182	169	150	123	147
D.O.Uptake, mg/l-hr	15.8	20.0	18.6	14.4	17.6	13.6	18.6	17.7
Dissolved Oxygen	7.6	5.7	6.1	6.7	7.1	7.3	4.9	6.2
Total Kjeldahl-N		115	146	123	90	154		199
Ammonia-N	13	18	21	24	14	20	9	13
Nitrate-N	0.8	0.9	1.5	1.1	1.2	0.8	1.1	0.9
Settlometer								
5 minutes	180	215	215	205	200	235	260	405
10 minutes	140	165	175	160	165	205	210	310
15 minutes	125	155	155	140	150	180	195	275
20 minutes	125	140	145	135	135	170	185	260
25 minutes	120	135	135	130	135	160	180	250
30 minutes	120	125	125	125	130	155	175	235
40 minutes	110	120	115	120	120	140	160	220
50 minutes	105	120	115	120	120	130	155	215
60 minutes	105	115	115	110	120	130	145	210

TABLE H-7

MARLBOROUGH - PHASE II

MIXED LIQUOR - SECOND STAGE - FIRST COMPARTMENT (2A) (mg/l)

Phase	IIA					IIB		
Date	5/8	5/9	5/10	5/11	5/12	5/16	5/17	5/18
Day	Mon	Tues	Wed	Thur	Fri	Tues	Wed	Thur
Total Solids	4080	3730	3650	3850	4110	4260	4650	1100
Total Volatile Solids	2470	2290	2220	2220	2510	2540	2740	600
Suspended Solids	3930	3300	3120	3360	3730	3790	4250	760
Volatile Susp. Solids	2300	2140	1950	2110	2370	2410	2690	560
pH	6.8	6.7	6.7	6.9	6.6	6.5	6.7	6.5
Temperature	13	13	13	13	13	13	14	13
Alkalinity	168	190	181	166	181	145	123	135
D.O.Uptake, mg/l-hr	67.3	60.0	72.0	75.8	86.8	65.1	21.2	9.9
Dissolved Oxygen	0.9	0.6	0.3	0.4	0.6	0.4	0.7	0.3
Total Kjeldahl-N		224	171	218	213	311	227	204
Ammonia-N	1.0	1.4	4.2	2.6	3.8	11	2.8	1.6
Nitrate-N	12	17	14	17	16	18	10	12

TABLE H-8

MARLBOROUGH - PHASE II

MIXED LIQUOR - SECOND STAGE - LAST COMPARTMENT (2B) (mg/l)

Phase	IIA					IIB		
Date	5/8	5/9	5/10	5/11	5/12	5/16	5/17	5/18
Day	Mon	Tues	Wed	Thur	Fri	Tues	Wed	Thur
Total Solids	4180	2950	4430	4500	4040	4490	4450	3980
Total Volatile Solids	2510	1760	2740	2640	2420	2680	2530	2460
Suspended Solids	3720	2480	3900	3990	3650	4020	4070	3610
Volatile Susp. Solids	2410	1610	2470	2500	2260	2510	2500	2410
pH	6.8	6.7	6.7	6.8	6.7	6.7	6.6	6.4
Temperature	13	13	13	13	13	13	14	13
Alkalinity	160	171	177	161	169	160	166	141
D.O.Uptake,mg/l-hr	9.0	10.2	13.0	10.9	13.2	12.5	10.3	10.0
Dissolved Oxygen	8.7	7.5	7.2	7.8	7.9	8.1	8.3	8.2
Total Kjeldahl-N		238	207	227	202	412	221	246
Ammonia-N	0.4	0.6	1.5	1.1	1.8	1.3	1.3	0.7
Nitrate-N	15	18	18	21	20	20	12	13
Settlometer								
5 minutes	430	400	390	440	440	400	490	400
10 minutes	330	300	300	320	340	300	300	300
15 minutes	280	270	270	280	290	270	260	260
20 minutes	250	240	250	250	260	250	240	240
25 minutes	240	230	230	240	240	230	230	220
30 minutes	230	220	220	230	230	220	210	210
40 minutes	210	200	200	210	220	200	200	200
50 minutes	200	190	200	200	200	200	200	200
60 minutes	200	190		200	200	200	190	200

TABLE H-9

MARLBOROUGH - PHASE II

RETURNED AND COMBINED SLUDGES (mg/l)

Phase	IIA					IIB		
Date	5/8	5/9	5/10	5/11	5/12	5/16	5/17	5/18
Day	Mon	Tues	Wed	Thur	Fri	Tues	Wed	Thur
Sludge Returned to First Stage Aeration								
Total Solids	2270	2900	2930	2520	2710	2890	2920	3850
Total Volatile Solids	1480	1970	2120	1680	1820	2010	2070	2650
Suspended Solids	1840	2460	2470	2100	2530	2540	2570	3450
Volatile Susp.Solids	1240	1810	1880	1580	1700	1930	1970	2490
Total Kjeldahl-N		182	230	193	218	272	179	333
Ammonia-N	18	17	19	20	15	12	10	14
Nitrate-N	1.5	1.0	1.2	1.2	1.0	1.1	0.9	0.7
Capillary Suction Time, sec	9.6	10.2	12.2	10.1	8.7	13.2	12.5	29.2
Return Rate, cu m/sec	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.07
(mgd)	(1.6)	(1.5)	(1.4)	(1.6)	(1.6)	(1.6)	(1.5)	(1.6)
Sludge Returned to Second Stage Aeration								
Total Solids	6930	6290	6910	5500	7600	6280	6550	5130
Total Volatile Solids	4190	3950	4230	3250	4540	3620	4290	3090
Suspended Solids	6430	5820	6390	5010	7280	5730	6100	4730
Volatile Susp. Solids	4050	3710	3990	3140	4510	3460	4160	3020
Total Kjeldahl-N		328	342	283	400	451	372	414
Ammonia-N	0.4	2.0	2.2	2.9	3.6	3.4	1.6	2.0
Nitrate-N	9	15	14	18	13	17	5.5	10
Capillary Suction Time, sec	8.9	8.0	7.2	8.4	8.7	8.2	8.8	9.0
Return Rate, cu m/sec	0.24	0.25	0.25	0.26	0.27	0.26	0.30	0.28
(mgd)	(5.5)	(5.5)	(5.7)	(6.0)	(6.1)	(6.0)	(6.9)	(6.3)

(continued)

TABLE H-9 (continued)

Phase	IIA					IIB		
Date	5/8	5/9	5/10	5/11	5/12	5/16	5/17	5/18
Day	Mon	Tues	Wed	Thur	Fri	Tues	Wed	Thur
Combined Primary, First and Second Stage Sludges								
Total Solids	27160	60230	68510	62590	81710	67510	61360	75410
Total Volatile Solids	17530	33040	38500	34990	32730	35580	35750	38820
Suspended Solids	25340	54680	64310	57950	75760	61610	57640	68750
Volatile Susp. Solids	16400	30040	35590	31760	30580	32510	33320	35340
Total Kjeldahl-N	1100	1860	1480	2110	1814	2010		1954
Ammonia-N	160	26	220	210	260	340	300	260
Nitrate-N	10	13	10	13	9	12	16	11
Total Phosphorous	500		2300	1450	6800	1250	1700	950
Capillary Suction Time, sec	347	131	388	408	101	426	323	233

TABLE H-10

MARLBOROUGH - PHASE II

VACUUM FILTER (mg/l)

Phase	IIA					IIB		
Date	5/8	5/9	5/10	5/11	5/12	5/16	5/17	5/18
Day	Mon	Tues	Wed	Thur	Fri	Tues	Wed	Thur
VACUUM FILTER FILTRATE								
COD-Total	3030	4770	5050	4820	3870	4080	4000	
COD-Soluble	2350	4060	4030	3910	3440	3120	3100	
BOD-Total	2050	3040	2400	3250	3570	2480	2540	4500
BOD-N Suppressed	1630	2820	2300	2650	2190	1980	1860	3150
Total Solids	7450	7830	7630	8540	6900	7780	8260	8230
Total Volatile Solids	2100	2090	2760	2320	1230	1990	2760	1340
Suspended Solids	1190	760	540	1380	630	750	1080	1260
Volatile Susp. Solids	310	290	160	350	210	370	360	320
pH	12.0	12.0	12.0		12.2	12.0	11.9	11.9
Total Kjeldahl-N		409	431		375			383
Ammonia-N	250		440	380	240	340	300	400
Nitrate-N			75	110		10	17	13
Total Phosphorous		10.5	16	10	8	24	13	7.5
VACUUM FILTER CAKE								
Total Solids, %	29.0	26.6	25.0	23.7	26.5	26.1	25.4	28.2
Total Volatile Solids, %	7.0	9.3	9.0	8.0	10.9	6.7	10.6	8.6
Quantity, kg/day	5394	8308	7317	7117	5903	5356	5242	6090
(lb/day)	(11892)	(18315)	(16131)	(15690)	(13013)	(11807)	(11556)	(13428)
Ferric Chloride, kg/day	167	190	173	179	145	167	151	156
(lb/day)	(369)	(418)	(381)	(394)	(320)	(369)	(332)	(344)
Lime, kg/day	4831	4444	2705	3671	3768	3188	3671	3478
(lb/day)	(10650)	(9789)	(5964)	(8094)	(8307)	(7029)	(8094)	(7668)

TABLE H-11

MARLBOROUGH - PHASES I AND II

HEAVY METALS (mg/l)

Phase	I							IIA		IIB
Date	4/18	4/20	4/25	4/27	5/2	5/4	5/5	5/9	5/10	5/17
Septage Loading % Flow								1.25		2.14
Influent										
Copper	0.16	0.22	0.15	0.17	0.18	0.21	0.30	0.16	0.22	0.20
Nickel	0.04	0	0.04	0.07	0.05	0	0.07	0	0	0
Chromium	0	0	0	0	0	0	0.25	0	0	0
Zinc	0.28	0.19	0.15	0.38	0.22	0.40	0.27	0.29	0.28	0.28
Cadmium	0.03	0	0.03	0.03	0	0	0.03	0.02	0	0
Lead	0.14	0.07	0.06	0.09	0.13	0	0	0	0.10	0.18
Primary Effluent										
Copper	0.30	0.10	0.13	0.17	0.15	0.16	0.21	0.15	0.24	0.16
Nickel	0.04	0	0.05	0.04	0.05	0.06	0.16	0.10	0	0.10
Chromium	0	0	0	0	0	0	0	0	0	0
Zinc	0.37	0.15	0.13	0.14	0.68	0.26	5.29	0.59	0.52	8.6
Cadmium	0.04	0	0	0.02	0.02	0	0	0	0	0
Lead	1.0	0.06	0.26	0.13	0.08	0.08	0.26	0	0.17	0.14
Secondary Effluent										
Copper	0.08	0.09	0.07	0.07	0.07	0.09	4.8	0.06	0.06	0.09
Nickel	0.06	0	0	0	0.05	0	0.06	0.03	0.07	0.11
Chromium	0	0	0	0	0	0	0	0	0	0.5
Zinc	0.20	0.23	0.17	0.17	0.14	0.15	3.96	0.11	0.13	0.21
Cadmium	0.03	0.03	0.03	0.03	0	0	0	0.03	0	0.03
Lead	0.18	0.10	0.12	0.10	0.07	0.25	0.15	0.0	0.16	0.07
Final Effluent										
Copper	0.10	0.06	0.20	0.07	0.08	0.08	0.06	0.26	0.07	0.07
Nickel	0.07	0	0.11	0	0.04	0.04	0.07	0	0	0.10
Chromium	0	0	0	0	0	0	0	0	0	0
Zinc	0.17	0.11	0.07	0.19	0.05	0.18		0.46	0.89	0.32
Cadmium	0	0	0.02	0	0	0.02	0	0.03	0	0
Lead	0	0	0.07	0	0.10	0.16	0.33	0.0	0.12	0
Septage										
Copper								15.4	21.2	13.4
Nickel								0.68	0.88	0.16
Chromium								1.48	2.52	1.0
Zinc								3.60	6.10	15.0
Cadmium								0.08	0	0.08
Lead								2.36	3.44	2.00

(continued)

TABLE H-11 (continued)

Phase	I							IIA		IIB
Date	4/18	4/20	4/25	4/27	5/2	5/4	5/5	5/9	5/10	5/17
Septage Loading								1.25		2.14
Vacuum Filter Filtrate										
Copper	0.37	0.42	0.45		0.33	0.45	0.40	0.37	0.38	0.38
Nickel	0.35	0.40	0.50		0.31	0.28	0.35	0.30	0.27	0.28
Chromium	0	0	0		0.25	0	0	0	0	0
Zinc	0.42	0.50	0.55		0.38	2.90	0.44	0.41	0.61	1.61
Cadmium	0.04	0.08	0.07		0.07	0.04	0.05	0.07	0.06	0.05
Lead	0.35	0.50	0.50		0.45	0.54	0.45	0.42	0.50	0.35
Combined Sludge										
Copper	7.1	34.8	33.8		19.0	39.6	45.2	48.4	44.0	42.8
Nickel	2.00	3.90	3.83		1.46	4.64	5.00	5.80	4.28	2.40
Chromium	5.50	1.3	12.5		7.5	10.0	8.20	16.0	9.2	11.2
Zinc	22.8	43.6	42.0		22.9	15.1	11.9	15.7	14.8	13.3
Cadmium	0.22	0.50	0.43		0.26	0.60	0.68	0.96	0.60	0.60
Lead	4.21	13.60	7.30		11.60	10.48	12.64	15.12	11.8	9.60
Cake mg/kg dry cake										
Copper	3305	4393	4806		3106	4964	4275	4779	4279	4312
Nickel	736	744	915		613	685	717	748	513	605
Chromium	1471	908	1526		958	1834	690	813	1300	1891
Zinc	8337	7261	9612		7163	5673	5985	13004	5921	6052
Cadmium	128	109	108		146	98	138	163	137	189
Lead	1178	1815	1678		1987	2127	1572	1853	1780	2043

APPENDIX I

TABLE I-1

MARLBOROUGH - PHASE III

SEPTAGE (mg/l)

Phase	IIIA			IIIB		
Date	5/30	5/31	6/1	6/7	6/8	6/8
Start Shock	7 am	7 am	7 am	7 am	7 am	2 pm
Length of Shock, min	30	30	30	110	120	15
Total Volume, gal	21000	21000	21000	39000	39000	12000
% of Avg. Daily Flow	0.81	0.84	0.84	1.8	2.3	
% of Flow During Shock	55	59	61	22	19	55
COD-Total	← 32260 →			21900	31200	
BOD-Total	← 7800 →			6080	9980	
BOD-N Suppressed	← 4970 →			5700	9300	
Total Solids	← 21160 →			11390	19590	
Total Volatile Solids	← 15300 →			8050	14660	
Suspended Solids	← 19610 →			8910	17130	
Volatile Susp. Solids	← 14450 →			6630	13140	
Total Kjeldahl-N	← 540 →			616	756	
Ammonia-N	← 190 →			260	190	
pH	← 5.8 →			5.2	5.3	
Alkalinity	← 744 →			959	1000	

TABLE I-2

MARLBOROUGH - PHASE III

INFLUENT (mg/l)

Phase	IIIA				IIIB		
Date	5/29	5/30	5/31	6/1	6/6	6/7	6/8
Day	Mon	Tues	Wed	Thur	Tues	Wed	Thur
Flow Rate, mgd	2.5	2.6	2.5	2.5	2.3	2.2	2.2
COD-Total	362	298	336	311	383	392	254
COD-Soluble	50.6	78.4	72.0	91.3	108.0	112.0	184.0
BOD-Total	147	117		78	138		98
BOD-N Suppressed	78	63		30	86		63
Total Solids	590	420	510	580	420	440	560
Total Volatile Solids	410	200	260	330	150	170	360
Suspended Solids	560	200	160	150	140	100	150
Volatile Susp. Solids	520	190	150	110	120	90	140
Total Kjeldahl-N	26	26	62		29	41	25
Ammonia-N	16	18	17	19	21	16	23
Nitrate-N	1.2	1.2	1.3	0.6	2.2	0.9	1.1
Alkalinity	117	127	130	108	140	128	133
pH	6.6	6.7	6.7	6.6	6.8	6.7	6.8

TABLE I-3

MARLBOROUGH - PHASE III

PRIMARY EFFLUENT (mg/l)

Phase	III A																
Date	5/29	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/31	5/31	5/31
Day	Mon	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Wed	Wed	Wed
Time	Com.	7am	7:30am	8am	8:30am	9am	10am	11am	12 noon	2pm	4pm	6pm	9pm	Com.	7am	7:30am	8am
Time After Shock, hrs.		0	½	1	1½	2	3	4	5	7	9	11	13		24/0	½	1
COD-Total	226	218	206	432	440	366	405	342	342	388	310	333	353	247	263	235	333
COD-Soluble	66.2	105	99.4	179	206	171	226	193	187	216	153	145	141	94.1	114	106	123
BOD-Total	78.0	78.0	75.0	162	183	144	185	176	168	195	117	153	177	114	88.5	84.0	108
BOD-N Suppressed	48.0	60.0	52.5	138	144	120	144	125	126	155	104	104	131	48.0	76.5	69.0	93.0
Total Solids	392	352	418	538	548	472	624	552	550	610	420	436	384	432	458	398	522
Total Volatile Solids	300	150	272	274	298	232	332	196	138	248	84	152	134	162	210	174	310
Suspended Solids	72	82	56	107	104	154	82	70	74	86	32	84	78	64	72	76	118
Volatile Susp. Solids	52	40	34	79	76	94	42	30	38	68	30	64	68	60	60	70	108
Total Kjeldahl-N	28.8	32.2	29.1	35.0	34.2	34.7	43.7	42.8	39.8	35.3	25.2	24.6			21.3		
Ammonia-N	19	19	19	21	21	25	29	28	26	24	22	14	14	22	18	20	29
Nitrate-N	0.9	1.1	1.0	1.1	1.0	1.0	1.2	0.8	1.3	1.6	1.6	1.0	1.1	1.3	1.3	1.2	1.1
Alkalinity	141	141	145	196	159	156	266	241	245	245	173	153	137	175	159	153	163
pH	7.1	7.2	7.2	7.1	6.5	6.7	8.5	8.6	8.6	8.6	8.2	7.2	7.1	7.0	7.0	7.0	6.9
Temperature		15													15		
Dissolved Oxygen-Top		1.1		0.4		0.3	0.3	0.3	0.3	0.2	0.4	2.2	1.5		0.2		0.2
Bottom		0.4		0.4		0.6	0.3	0.3	0.2	0.2	0.3	0.4	0.3		0.4		0.7

(continued)

TABLE I-3 (continued)

Phase	III A																
Date	5/31	5/31	5/31	5/31	5/31	5/31	5/31	5/31	5/31	5/31	6/1	6/1	6/1	6/1	6/1	6/1	6/1
Day	Wed	Wed	Wed	Wed	Wed	Wed	Wed	Wed	Wed	Wed	Thur	Thur	Thur	Thur	Thur	Thur	Thur
Time	8:30am	9am	10am	11am	12noon	2pm	4pm	6pm	10:30pm	Com.	7am	7:30am	8am	8:30am	9am	10am	11am
Time After Shock, hrs.	1½	2	3	4	5	7	9	11	15½		24/0	½	1	1½	2	3	4
COD-Total	591	512	369	337	365	344	324	296	348		228	264	364	472	401	376	349
COD-Soluble	222	163	179	194	191	212	100	124	144		76	108	116	124	163	183	206
BOD-Total	204	180	162	192	270	168	147	120	174	63.0	81.0		96.0	99.0	141	141	174
BOD-N Suppressed	196		132	78.0	90.0	128	110	84.0	135	42.0	61.5		60.0	75.0	113	114	125
Total Solids	672	584	574	562	598	712	654	614	546		452	450	494	526	594	576	560
Total Volatile Solids	374	344	288	268	268	260	228	196	260		188	198	304	288	286	246	238
Suspended Solids	200	112	116	100	84	194	186	168	154		68	64	168	92	142	78	66
Volatile Susp. Solids	176	100	96	96	70	68	70	66	54		62	60	156	60	124	62	54
Total Kjeldahl-N		37.8			45.4						31.9				37.2		
Ammonia-N	29	30	30	28	28	30	20	18	18		23	21	24	24	28	38	38
Nitrate-N	1.9	1.8	1.1	1.5	1.5	1.8	1.0	1.3	0.7		1.5	1.2	1.0	1.3	1.8	1.4	1.5
Alkalinity	179	179	235	259	264	278	182	161			164	157	150	148	180	235	263
pH	6.8	6.9	7.8	8.3	8.3	8.5	7.3	7.1			7.0	6.8	6.8	6.6	7.0	8.2	8.5
Temperature											16						
Dissolved Oxygen-Top		0.1	0.2	0.1	0.1	1.7	1.4	1.4	1.2		0.3		0.1		0.3	0.4	0.3
Bottom		0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2		0.4		0.3		0.3	0.3	0.2

(continued)

TABLE I-3 (continued)

Phase	III A							III B								
Date	6/1	6/1	6/1	6/1	6/1	6/2	6/2	6/6	6/7	6/7	6/7	6/7	6/7	6/7	6/7	6/7
Day	Thur	Thur	Thur	Thur	Thur	Fri	Fri	Tues	Wed	Wed	Wed	Wed	Wed	Wed	Wed	Wed
Time	12noon	2pm	4pm	6pm	Com.	7am	9am	Com.	7am	7:30am	8am	8:30am	9am	10am	11am	12noon
Time After Shock, hrs.	5	7	11	13		24	26		0	½	1	1½	2	3	4	5
COD-Total	381	635	290	508	222	276		243	247	223	379	916	745	622	450	438
COD-Soluble	210	222	159	341	74.8	98.4		75.7	104	104	91.6	290	295	275	211	211
BOD-Total	159	177	141	129	63.0	90.0		84.0	111		126	345	330	285	189	156
Bod-N Suppressed	128	131	110	102	42.0	76.5		49.5	73.5	58.5	70.5	273	243	240	165	112
Total Solids	584	634	564	500	516	536		400	464	458	616	848	718	694	622	592
Total Volatile Solids	240	294	246	102	176	226		94	172	190	346	546	398	336	272	262
Suspended Solids	63	54	78	86	92	128		50	76	86	248	540	204	160	100	84
Volatile Susp. Solids	60	46	67	70	62	120		40	52	38	200	492	184	140	92	80
Total Kjeldahl-N	44.5					35.0			33.3				48.4			46.2
Ammonia-N	35	25	22	19	22	22		23	18	17	20	35	31	41	33	38
Nitrate-N	1.4	1.5	0.7	2.0	1.2	1.4		0.9	1.0	1.1	1.4	1.2	1.5	1.2	0.6	1.2
Alkalinity	259	247	195	150	182	142		144	161	165	213	203	208	233	255	251
pH	8.7	8.8	8.1	6.9	7.0	7.1		7.2	7.2	7.2	6.9	6.9	6.9	7.1	8.4	8.5
Temperature						16			17							
Dissolved Oxygen-Top	0.4	0.9	1.2	1.5		0.3	0.1		0.2		0.1		0.1	0.1	0.2	0.1
Bottom	0.2	2.0	1.3	0.9		0.3	0.2		0.3		0.2		0.2	0.1	0.1	0.1

(continued)

TABLE I-3 (continued)

Phase									III B											
Date	6/7	6/7	6/7	6/7	6/8	6/8	6/8	6/8	6/8	6/8	6/8	6/8	6/8	6/8	6/8	6/8	6/9	6/9	6/9	6/9
Day	Wed	Wed	Wed	Wed	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Fri	Fri	Fri	Fri
Time	2pm	4pm	6pm	Com.	7am	7:30am	8am	8:30am	9am	10am	11am	12noon	2pm	4pm	6pm	Com.	7am	8am	9am	10am
Time After Shock, hrs.	7	9	11		24/0	½	1	1½	2	3	4	5	7/0	9/2	11/4		24/17			
COD-Total	384	332	340	252	248	292	632	1128	1128	876	688	633	488	387	371	309	313			
COD-Soluble	188	164	184	88.0	96.0	104	240	440	484	420	371	270	246	191	238	85.9	145			
BOD-Total	213	216	171	103	99.0	105	198	518	443	420	368	336	264	252	222	135	150			
BOD-N Suppressed	122	113	118	93.0		81.0	188	456	383	381	155	209	207	229	183	82.5	113			
Total Solids	564	494	526	502	470	476	668	962	970	842	918	722	806	598	490	516	400			
Total Volatile Solids	226	210	240	274	230	238	420	600	588	526	452	316	332	142	166	192	174			
Suspended Solids	74	48	44	74	62	90	224	260	407	227	284	196	190	80	52	152	46			
Volatile Susp. Solids	60	46	42	52	50	74	162	196	293	166	164	108	110	76	50	128	44			
Total Kjeldahl-N					30.5				65.2			51.8								
Ammonia-N	25	19	19	21	19	18	21	29	34	36	45	40	36	23	22	31	14			
Nitrate-N	1.3	0.7	1.2	1.3	1.2	1.3	0.6	1.0	1.5	1.7	1.5	1.4	1.3	0.9	1.2	1.0	1.2			
Alkalinity	195	166	155	179	164	161	167	183	215	252	271	243	260	174	167	201	150			
pH	7.2	6.9	6.8	7.0	7.0	6.4	6.7	6.4	6.6	7.0	7.3	7.6	7.8	6.8	6.9	7.2	6.8			
Temperature					17												18			
Dissolved Oxygen-Top	0.2	0.4	0.3		0.4		0.2		0.2	0.3	0.1	0.1	0.1	0.1	0.2		0.2	1.0	0.4	0.5
Bottom	0.1	0.2	0.1		0.3		0.2		0.3	0.1	0.1	0.1	0.1	0.2	0.2		0.3	0.2	0.2	0.2

TABLE I-4

MARLBOROUGH - PHASE III

SECONDARY EFFLUENT (mg/1)

Phase	IIIA																	
Date	5/29	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/31	5/31	5/31	5/31	5/31	5/31
Day	Mon	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Wed	Wed	Wed	Wed	Wed	Wed
Time	Comp	7am	8am	9am	10am	11am	noon	2pm	4pm	6pm	9pm	Comp	7am	8am	9am	10am	11am	noon
Time after shock, hrs.		0	1	2	3	4	5	7	9	11	14		24/0	1	2	3	4	5
COD-Total	50.6	54.5	62.3	113	70.0		31.1	62.7	59.5	79.4	71.4	55.6	79.4	67.5	60.0	56.0		60.0
COD-Soluble	46.7	54.5	23.4	42.8	54.5		31.1	51.0	58.8	47.1	54.9	47.1	47.1	54.9	36.0	44.0		40.0
BOD-Total	8.4	7.2	6.4	10.4	9.6		8.0	8.6	9.0	10.0	13.4	10.2	5.6	9.0	7.0	7.2		11.2
BOD-N Suppressed	0.0		0.4	1.6	1.6		2.8	3.2	2.3	3.5	2.4	2.0	1.7	3.0	2.4	2.4		9.3
Total Solids	266	326	350	304	296		318	354	352	332	202	332	358	376	356	374		438
Total Volatile Solids	32	172	166	20	58		52	88	56	34	22	94	92	150	106	114		122
Suspended Solids	9	15	11	10	8		6	20	25	22	4	24	10	9	13	5		6
Volatile Susp. Solids	3	5	6	5	3		2	13	15	13	3	16	9	9	11	3		5
Total Kjeldahl-N	17.4	18.9	19.0	18.5	19.5		21.7	23.4	23.5	21.7	19.2		17.9			17.2		
Ammonia-N	15	18	16	17	16		20	20	24	19	19	18	17	19	18	18		22
Nitrate-N	4.1	0.1	1.8	1.6	1.5		1.5	1.9	1.5	1.8	2.0	4.0	1.7	1.5	1.8	1.7		1.8
Alkalinity	116	135	140	139	149		163	186	197	199	186	142	160	166	163	159		168
pH	7.1	7.3	7.0	7.0	7.0		7.1	7.4	7.4	7.4	7.4	7.1	7.1	7.2	7.3	7.3		7.2
Temperature ,^{o}C		17											17					
Dissolved Oxygen		3.8	2.8	3.0	2.5	1.7	0.9	0.2	0.4	1.0	0.4		1.5	1.6	2.4	2.2	1.8	1.5

(continued)

TABLE I-4 (continued)

Phase	IIIA																
Date	5/31	5/31	5/31	5/31	5/31	6/1	6/1	6/1	6/1	6/1	6/1	6/1	6/1	6/1	6/1	6/2	6/2
Day	Wed	Wed	Wed	Wed	Wed	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Fri	Fri
Time	2pm	4pm	6pm	10:30 pm	Comp	7am	8am	9am	10am	11am	noon	2pm	4pm	6pm	Comp	7am	9am
Time after shock, hrs.	7	9	11	15½		24/0	1	2	3	4	5	7	9	11		24	26
COD-Total	76.0	72.0	64.0	72.0		60.0	64.0	60.0	68.0		63.5	55.6	67.5	55.6	43.4	66.9	
COD-Soluble	56.0	48.0	44.0	56.0		48.0	48.0	68.0	48.0		43.7	27.8	39.7	51.6	43.3	63.0	
BOD-Total	13.8	9.0	8.8	10.0		8.2	4.4	4.0	10.6		6.8	6.0	6.0	8.0	12.2	10.4	
BOD-N Suppressed	3.3	2.1	2.1	2.1		2.1	1.5	0.6	0.9		5.4	5.4	7.2	8.2	11.6	4.5	
Total Solids	516	538	528	488		356	364	378	366		350	452	422	426	430	406	
Total Volatile Solids	114	88	72	122		100	182	80	86		86	180	162	102	104	122	
Suspended Solids	43	45	39	42		7	5	19	7		1	15	3	7	11	7	
Volatile Susp. Solids	14	11	10	11		7	5	18	7		1	14	2	6	5	5	
Total Kjeldahl-N						20.2			20.2			23.9					
Ammonia-N	22	22	22	20		19	20	24	18		23	21	23	22	17	19	
Nitrate-N	1.9	2.0	1.8	2.2		1.5	1.4	1.8	1.9		1.8	1.6	2.0	2.2	4.7	1.8	
Alkalinity	176	209	207			156	157	158	153		169	179	203	205	158	162	
pH	7.2	7.3	7.3			7.1	7.3	7.2	7.1		7.0	7.1	7.4	7.2	7.1	7.2	
Temperature, ^{0}C						17										17	
Dissolved Oxygen	1.5	0.8	0.6	0.4		0.8	1.4	1.3	1.8	1.1	0.7	0.2	0.2	0.3		2.0	2.6

(continued)

TABLE I-4 (continued)

Phase	IIIB																
Date	6/6	6/7	6/7	6/7	6/7	6/7	6/7	6/7	6/7	6/7	6/8	6/8	6/8	6/8	6/8	6/8	6/8
Day	Tues	Wed	Wed	Wed	Wed	Wed	Wed	Wed	Wed	Wed	Thur	Thur	Thur	Thur	Thur	Thur	Thur
Time	Comp	7am	8am	9am	10am	noon	2pm	4pm	6pm	Comp	7am	8am	9am	10am	noon	2pm	4pm
Time after shock, hrs.		0	1	2	3	5	7	9	11		24/0	1	2	3	5	7/0	9/2
COD-Total	51.8	43.8	39.8	39.8	51.8	51.8	60.0	72.0	72.0	52.0	56.0	48.0	36.0	40.0	78.1	66.4	74.0
COD-Soluble	43.8	43.8	35.9	39.8	51.8	43.8	48.0	52.0	52.0	40.0	44.0	28.0	28.0	36.0	46.8	39.1	51.0
BOD-Total	5.4	2.4	2.0	2.8	2.8	5.6	5.0	5.2	3.8	6.6	2.4	3.0	3.4	8.2	9.0	10.6	8.4
BOD-N Suppressed	0.8		0.5	1.2	0.2	2.0	1.8	0.8	0.8	0.2	0.3		0.8	4.4	2.9	3.9	2.1
Total Solids	406	462	414	426	428	418	418	408	388	420	418	468	490	416	446	478	454
Total Volatile Solids	60	182	102	112	110	124	82	60	68	108	204	264	176	226	84	66	40
Suspended Solids	3	6	9	2	3	4	4	1	1	6	9	6	2	4	17	23	11
Volatile Susp. Solids	2	2	2	1	2	3	3	1	1	2	4	2	6	3	7	10	10
Total Kjeldahl-N		18.6			18.2		23.1				16.9			17.9		23.8	
Ammonia-N	18	16	17	18	17	26	21	20	20	17	16	15	19	22	23	27	21
Nitrate-N	5.5	2.6	2.2	2.3	2.0	3.0	2.0	2.3	1.6	6.5	2.3	3.2	3.4	2.5	2.0	1.0	0.9
Alkalinity	193	210	194	191	198	201	218	215	216	180	181	174	181	183	202	218	228
pH	7.4	7.7	7.9	7.8	8.1	7.8	7.5	7.9	7.7	7.3	7.7	7.6	7.4	7.5	7.5	7.5	7.4
Temperature, ^{o}C		16									18						
Dissolved Oxygen		1.0	1.8	2.1	1.6	0.2	0.2	0.2	0.2		0.7	1.0	0.9	0.1	0.1	0.1	0.2

(continued)

TABLE I-4 (continued)

Phase	IIIB						
Date	6/8	6/8	6/9	6/9	6/9	6/9	6/9
Day	Thur	Thur	Fri	Fri	Fri	Fri	Fri
Time	6pm	Comp	7am	8am	9am	10am	11am
Time after shock, hrs.	11/4		24/17				
COD-Total	58.6	46.8	54.7				
COD-Soluble	54.7	43.0	50.8				
BOD-Total	8.0	8.2	4.2				
BOD-N Suppressed	2.4	2.0	2.3				
Total Solids	440	366	366				
Total Volatile Solids	36	72	86				
Suspended Solids	5	1	5				
Volatile Susp. Solids	5	0	4				
Total Kjeldahl-N							
Ammonia-N	19	18	14				
Nitrate-N	1.7	6.0	1.8				
Alkalinity	226	166	184				
pH	7.6	7.0	7.4				
Temperature, ^{o}C			18				
Dissolved Oxygen	0.2		0.3	0.1	0.4	1.7	1.1

TABLE I-5

MARLBOROUGH - PHASE III

FINAL EFFLUENT (mg/1)

Phase	III A																		
Date	5/29	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/31	5/31	5/31	5/31	5/31	5/31	5/31
Day	Mon	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Wed	Wed	Wed	Wed	Wed	Wed	Wed
Time	Comp	7am	8am	9am	10am	11am	noon	2pm	4pm	6pm	9pm	Comp	7am	8am	9am	10am	11am	noon	2pm
Time after shock, hrs.		0	1	2	3	4	5	7	9	11	13		24/0	1	2	3	4	5	7
COD-Total	23.4	50.6		38.9		38.9	38.9	39.7	47.6	47.6	59.5	54.9	39.2		44.0	36.0		40.0	47.6
COD-Soluble	15.6	27.2		35.0		27.2	23.4	39.7	39.7	43.7	39.2	47.1	35.3		24.0	28.0		32.0	47.6
BOD-Total	2.4	3.4		2.2		4.1	4.4	12	>12	2.2	>12	1.1	2.1		2.0	4.0			2.1
BOD-N Suppressed	0.3	0.4		0.3		0.6	0.4	1.1	0.8	0.2	0.6	0.4	0.7		0.3	0.3			0.5
Total Solids	372	444		334		330	354	390	358	338	316	390	436		408	428		454	572
Total Volatile Solids	178	180		58		126	22	116	110	88	62	142	146		134	202		156	148
Suspended Solids	11	15		7		8	9	24	7	15	3	13	15		11	3		7	42
Volatile Susp. Solids	5	5		3		4	1	14	6	10	2	11	11		9	3		6	11
Total Kjeldahl-N	2.8	2.8		4.1		2.0	2.2	2.4	2.5		2.8		2.2			2.1			2.0
Ammonia-N	0.2	0.3		0.5		1.0	0.5	0.7	1.1	0.8	0.6	0.8	0.3		0.7	0.8		0.6	0.4
Nitrate-N	17	19		19		24	17	18	18	19	19	19	18		20	18		19	18
Alkalinity	46	59		57		38	62	62	57	58	64	56	66		80	84		77	76
pH	6.8	7.0		6.7		6.2	6.6	6.8	6.8	6.8	6.8	7.0	6.9		7.0	7.1		6.9	7.0
Temperature, ^0C		17											17						
Dissolved Oxygen		5.3	5.2	4.8	3.0	1.7	0.5	0.2	0.3	0.4	0.4		3.0	3.4	3.5	2.4	1.9	1.4	0.8

(continued)

TABLE 1-5 (continued)

Phase	III A																		
Date	5/31	5/31	5/31	5/31	6/1	6/1	6/1	6/1	6/1	6/1	6/1	6/1	6/1	6/1	6/2	6/2	6/6	6/7	6/7
Day	Wed	Wed	Wed	Wed	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Fri	Fri	Tues	Wed	Wed
Time	4pm	6pm	10:30 pm	Comp	7am	8am	9am	10am	11am	noon	2pm	4pm	6pm	Comp	7am	9am	Comp	7am	8am
Time after shock, hrs.	9	11	15½		24/0	1	2	3	4	5	7	9	11		24	26		0	1
COD-Total	55.6	44.0	40.0	44.0			32.0	43.7		43.7	43.7	39.7	35.7	39.4	51.2		20.0	35.9	
COD-Soluble	32.0	36.0	38.0	32.0			36.0	27.8		39.7	31.7	31.7	31.7	35.4	47.2			43.8	
BOD-Total	4.4	12	12	2.9	3.2			10.5		5.0	10.6	10.0	9.2	1.1	9.2		1.1		
Bod-N Suppressed	0.5	1.3	1.2	1.7	0.6			0.9		0.2	0.2	1.6	1.2		1.1		0.9	0.4	
Total Solids	576	582	568	448	464		472	466		416	460	404	464	536	532		426	500	
Total Volatile Solids	124	150	184	224	146		168	160		158	246	138	170	202	170		60	84	
Suspended Solids	45	42	42	3	2		30	9		1	5	4	8	13	10		8	8	
Volatile Susp. Solids	11	13	13	3	1		25	7		1	4	3	7	8	9		3	2	
Total Kjeldahl-N					2.7			2.2			2.4			2.7				2.2	
Ammonia-N	0.1	0.2	1.0	0.6	0.2		0.2	0.2		0.8	0.7	0.6	1.2	1.3	0.8		0.5	0.2	
Nitrate-N	20	20	20	20	20		20	20		20	22	22	26	23	25		23	23	
Alkalinity	65	59		54	59		52	59		48	55	56	56	57	54		89	104	
pH	6.9	6.4		6.8	6.7		6.6	6.5		6.2	6.6	6.5	6.4	6.5	6.5		7.2	6.6	
Temperature					17													16	
Dissolved Oxygen	0.3	0.3	0.4		2.0	2.1	2.3	1.2	0.6	0.4	0.2	0.3	0.2		4.3	4.9		3.0	4.0

(continued)

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TABLE I-5 (continued)

Phase								III B											
Date	6/7	6/7	6/7	6/7	6/7	6/7	6/7	6/8	6/8	6/8	6/8	6/8	6/8	6/8	6/8	6/8	6/9	6/9	6/9
Day	Wed	Wed	Wed	Wed	Wed	Wed	Wed	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Fri	Fri	Fri
Time	9am	10am	noon	2pm	4pm	6pm	Comp	7am	8am	9am	10am	noon	2pm	4pm	6pm	Comp	7am	8am	7am
Time after shock, hrs.	2	3	5	7	9	11		24/0	1	2	3	5	7/0	9/2	11/4		24/17		
COD-Total	39.8	31.9	31.9	44.0	40.0	44.0	28.0	24.0		28.0	36.0	39.1	35.2	47.0	54.7	43.0	39.1		
COD-Soluble	27.9	27.9	23.9	44.0	36.0	52.0	16.0	16.0		12.0	16.0	27.3	31.1	43.0	35.2	43.0	35.2		
BOD-Total		20.3					1.6												
BOD-N Suppressed	1.1	1.4	0.4	0.7	1.3	2.3		3.2	9.0			2.0	2.0	1.9	1.4	1.1			
Total Solids	510	476	476	480	464	456	472	480		492	434	532	536	498	488	456	426		
Total Volatile Solids	106	80	106	98	74	48	150	140		128	146	114	110	50	62	106	126		
Suspended Solids	6	5	5	2	2	2	6	4		8	7	16	16	8	5	8	4		
Volatile Susp. Solids	4	4	4	1	2	2	3	2		4	4	6	6	7	5	7	4		
Total Kjeldahl-N		3.1		2.7				1.8			2.0		2.1			2.4	2.4		
Ammonia-N		0.3	0.4	0.5	0.3	0.4	0.5	0.2		0.5	0.7	1.0	0.8	0.8	0.3	2.4	1.2		
Nitrate-N		21	26	26	23	24	23	22		21	24	19	17	17	19	20	22		
Alkalinity	108	106	99	101	100	99	96	90		91	89	85	83	81	80	82	81		
pH	6.7	7.1	7.1	6.9	6.5	6.3	6.6	6.5		6.7	6.6	6.5	6.5	6.5	6.5	6.7	6.6		
Temperature, ^0C								18									18		
Dissolved Oxygen	4.0	2.4	1.8	1.2	0.6	0.6		4.7	5.2	4.0	3.4	2.5	1.8	0.2	0.2		2.2	2.5	2.5

TABLE I-6

MARLBOROUGH - PHASE III

MIXED LIQUOR - FIRST STAGE (mg/l)

Phase	III A																		
Date	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/31	5/31	5/31	5/31	5/31	5/31	5/31	5/31	5/31
Day	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Wed	Wed	Wed	Wed	Wed	Wed	Wed	Wed	Wed
Time	7am	8am	9am	10am	11am	noon	2pm	4pm	6pm	8pm	7am	8am	9am	10am	11am	noon	2pm	4pm	6pm
Time after shock, hrs.	0	1	2	3	4	5	7	9	11	13	24/0	1	2	3	4	5	7	9	11
Total Solids	1460		1570		1620			1800			2070							1980	
Total Volatile Solids	950		930		980			1080			1350							1160	
Suspended Solids	1070		1220		1160			1330			1620							1400	
Volatile Susp. Solids	740		890		820			940			1180							1010	
pH	6.9		6.9		7.0			6.8			6.7							6.8	
Temperature, °C	16										16								
Alkalinity	210		206		237			343			298							343	
D.O. Uptake, mg/l-hr.	18.8	16.5	26.3	24.8	24.9	18.6	25.1	22.8	20.8		20.3	19.9	17.5	21.6	25.0	23.6	23.9	22.0	22.2
Dissolved Oxygen	6.6	6.4	4.9	3.8	3.1	2.1	3.6	4.5	5.4	5.2	6.4	6.4	4.8	4.8	4.5	4.1	3.9	3.1	3.6
Total Kjeldahl-N	134		112		129						151								
Ammonia-N	20		19		24			20			20							35	
Nitrate-N	1.0		1.1		1.1			1.3			1.3							1.1	
Settlometer																			
5 minutes	190	190	180	180	180	190	200	220	220		240	210	210	230	230	250	240	250	250
10 minutes	140	140	140	140	150	160	170	170	170		190	170	170	180	190	190	185	200	200
15 minutes	130	130	130	130	140	140	150	160	150		170	150	150	160	170	170	170	180	180
20 minutes	120	130	120	120	130	130	140	150	140		160	140	140	150	160	165	160	170	170
25 minutes	120	120	120	115	120	130	130	140	140		150	130	135	140	140	155	150	160	160
30 minutes	115	120	110	110	120	120	120	130	130		145	130	130	140	140	145	145	150	150
40 minutes	110	115	110	105	115	110	120	120			135	120	120	130	130	140	140	145	
50 minutes	105	110	100	105	110	110	120	120			135	120	120	120	130	130	130	140	
60 minutes	105	110	100	100	110	110	120	110			130	120	120	120	130	130	130	130	

(continued)

TABLE I-6 (continued)

Phase	III A												III B				
Date	5/31	6/1	6/1	6/1	6/1	6/1	6/1	6/1	6/1	6/1	6/2	6/2	6/7	6/7	6/7	6/7	6/7
Day	Wed	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Fri	Fri	Wed	Wed	Wed	Wed	Wed
Time	10:30 pm	7am	8am	9am	10am	11am	noon	2pm	4pm	6pm	7am	9am	7am	8am	9am	10am	11am
Time after shock, hrs.	15½	24/0	1	2	3	4	5	7	9	11	25	27	0	1	2	3	4
Total Solids		2290							2050		2320		2250				
Total Volatile Solids		1510							1260		1560		1260				
Suspended Solids		1860							1540		1910		1830				
Volatile Susp. Solids		1350							1150		1390		1160				
pH		6.8							6.9		7.0		7.3				
Temperature, °C		16									16		16.5				
Alkalinity		300							328		220		191				
D.O. Uptake, mg/l-hr		22.4	18.9	20.9	24.6	23.8	25.5	8.9	24.9	22.2	30.0		17.7	19.4	24.7	28.9	31.9
Dissolved Oxygen	2.6	5.4	5.3	3.8	3.3	2.2	1.5	3.5	4.3	5.3	7.6	7.5	5.2	5.4	1.6	1.0	1.4
Total Kjeldahl-N											162		168				
Ammonia-N		24							39		20		17				
Nitrate-N		1.4							1.7		1.1		1.6				
Settlometer																	
5 minutes		300	220	220	235	240	260	250	270	270	300		370	220	230	235	240
10 minutes		240	185	175	200	200	200	210	210	220	240		210	180	185	190	190
15 minutes		210	160	160	170	170	180	190	195	200	210		180	150	160	170	170
20 minutes		200	150	150	160	160	170	170	180	180	200		165	140	150	160	155
25 minutes		185	140	140	150	155	165	160	170	170	190		160	135	145	150	150
30 minutes		170	140	135	145	150	150	150	160	160	180		150	130	140	140	145
40 minutes		170	130	130	140	140	140	140	150		170		140	120	130	135	130
50 minutes		160	130	130	130	130	130	140	140		160		130	115	125	125	130
60 minutes		155	130	120	130	130	130	130	140		150		130	115	120	120	125

(continued)

TABLE I-6 (continued)

Phase	III B																		
Date	6/7	6/7	6/7	6/7	6/8	6/8	6/8	6/8	6/8	6/8	6/8	6/8	6/8	6/8	6/9	6/9	6/9	6/9	6/9
Day	Wed	Wed	Wed	Wed	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Fri	Fri	Fri	Fri	Fri
Time	noon	2pm	4pm	6pm	7am	8am	9am	10am	11am	noon	2pm	3pm	4pm	6pm	7am	8am	9am	10am	11am
Time after shock, hrs.	5	7	9	11	24/0	1	2	3	4	5	7	8	9	11	24	25	26	27	28
Total Solids			2560		1960								2510		3010				
Total Volatile Solids			1520		1100								1420		1880				
Suspended Solids			2120		1540								2020		2650				
Volatile Susp. Solids			1430		960								1060		1770				
pH			6.7		6.8								7.2		7.1				
Temperature, ^{o}C					17.5										18				
Alkalinity			364		284								353		300				
D.O. Uptake, mg/l-hr	30.0	29.0	28.3	27.1	22.6	22.7	34.3	34.8	36.7	34.4	37.5		36.4		30.6				
Dissolved Oxygen	1.2	3.4	4.1	4.1	6.3	6.1	1.5	1.3	1.1	1.0	1.0	1.4	1.3	2.2	4.7	5.1	5.2	4.9	4.7
Total Kjeldahl-N																			
Ammonia-N			22		14								23		19				
Nitrate-N			1.3		1.2								1.4		1.3				
Settlometer																			
5 minutes	240	250	270	270	285	265	250	270	280	270	270		310		315				
10 minutes	190	200	220	220	235	200	200	220	230	220	240		250		255				
15 minutes	170	180	190	185	200	160	180	195	200	200	210		225		225				
20 minutes	160	165	175	175	185	155	170	170	180	190	190		210		210				
25 minutes	145	160	165	170	180	150	155	170	170	180	185		200		190				
30 minutes	140	150	160	160	170	150	150	160	170	170	175		190		185				
40 minutes	130	140	150		155	140	135	150	155	160	160		180		175				
50 minutes	130	135	140		150	135	135	140	150	150	155		170		170				
60 minutes	120	130	140		145	130	130	135	140	150	150		160		160				

TABLE I-7

MARLBOROUGH - PHASE III

MIXED LIQUOR - SECOND STAGE - FIRST COMPARTMENT (mg/l)

Phase	IIIA															
Date	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/31	5/31	5/31	5/31	5/31	5/31
Day	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Wed	Wed	Wed	Wed	Wed	Wed
Time	7am	8am	9am	10am	11am	noon	2pm	4pm	6pm	8pm	7am	8am	9am	10am	11am	noon
Time, After Shock, hrs.	0	1	2	3	4	5	7	9	11	13	24/0	1	2	3	4	5
Total Solids	2730			2280				2290			2640					
Total Volatile Solids	1710			1270				1290			1570					
Suspended Solids	2300			1960				1960			2220					
Volatile Susp. Solids	1500			1220				1210			1440					
pH	6.8			6.7				6.4			6.6					
Temperature, °C	17										16.5					
Alkalinity	144			127				148			194					
D.O.Uptake, mg/l-hr	28.4	74.0	57.1	94.7	84.4	74.0	101.9	93.1	81.8		8.0	76.1	78.3	85.7	84.4	85.7
Dissolved Oxygen	1.2	0.8	0.6	0.3	0.3	0.3	0.2	0.3	0.3	1.2	0.3	0.3	0.3	0.3	0.2	0.2
Total Kjeldahl-N	165			123							126					
Ammonia-N	2.1			6.0				9.0			3.5					
Nitrate-N	11			11				9.5			15					

(continued)

TABLE I-7 (continued)

Phase	IIIA														
Date	5/31	5/31	5/31	5/31	6/1	6/1	6/1	6/1	6/1	6/1	6/1	6/1	6/1	6/2	6/2
Day	Wed	Wed	Wed	Wed	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Fri	Fri
Time	2pm	4pm	6pm	10:30 pm	7am	8am	9am	10am	11am	noon	2pm	4pm	6pm	7am	9am
Time After Shock, hrs.	7	9	11	15½	24/0	1	2	3	4	5	7	9	11	24	26
Total Solids		2540			2480							2280		2810	
Total Volatile Solids		1400			1480							1300		1660	
Suspended Solids		2030			2080							1870		2290	
Volatile Susp. Solids		1300			1350							1230		1420	
pH		6.4			6.4							6.5		6.5	
Temperature, ^{o}C					17									17	
Alkalinity		148			141							152		123	
D.O.Uptake, mg/l-hr	80.6	91.5	78.3		11.0	76.1	78.3	83.1	85.7	83.1	90.0	85.7	81.8	11.1	
Dissolved Oxygen	0.2	0.2	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.6	0.3	0.4	0.7	0.5	0.9
Total Kjeldahl-N															
Ammonia-N		8.0			3.7							6.5		1.4	
Nitrate-N		13			17							8.5		19	

(continued)

TABLE I-7 (continued)

Phase	IIIB															
Date	6/7	6/7	6/7	6/7	6/7	6/7	6/7	6/7	6/7	6/8	6/8	6/8	6/8	6/8	6/8	6/8
Day	Wed	Wed	Wed	Wed	Wed	Wed	Wed	Wed	Wed	Thur	Thur	Thur	Thur	Thur	Thur	Thur
Time	7am	8am	9am	10am	11am	noon	2pm	4pm	6pm	7am	8am	9am	10am	11am	noon	2pm
Time After Shock, hrs	0	1	2	3	4	5	7	9	11	24/0	1	2	3	4	5	7
Total Solids	2240							1970		2330						
Total Volatile Solids	1310							1140		1350						
Suspended Solids	1760							1520		1860						
Volatile Susp. Solids	1190							1080		1150						
pH	6.9							6.5		6.5						
Temperature, ^{o}C	16															
Alkalinity	122							191		139						
D.O.Uptake,mg/l-hr	7.0	74.0	93.1	78.3	79.4	88.5	100.0	93.1	88.5	7.4	69.2	85.7	70.1	70.1	73.0	100.0
Dissolved Oxygen	0.4	0.4	0.3	0.4	0.4	0.3	0.3	0.2	0.4	0.4	0.4	0.4	0.2	0.2	0.2	0.2
Total Kjeldahl-N	140															
Ammonia-N	1.6							4.1		4.5						
Nitrate-N	20							15		19						

(continued)

TABLE I-7 (continued)

Phase	IIIB							
Date	6/8	6/8	6/8	6/9	6/9	6/9	6/9	6/9
Day	Thur	Thur	Thur	Fri	Fri	Fri	Fri	Fri
Time	3pm	4pm	6pm	7am	8am	9am	10am	11am
Time After Shock, hrs	8	9	11	24	25	26	27	28
Total Solids		2140		2240				
Total Volatile Solids		1210		1350				
Suspended Solids		1740		1760				
Volatile Susp. Solids		880		1200				
pH		6.7		6.3				
Temperature, °C		18		18				
Alkalinity		164		128				
D.O.Uptake, mg/l hr		98.2		75.8				
Dissolved Oxygen	0.4	1.0	0.9	0.5	0.5	0.4	0.4	0.4
Total Kjeldahl-N				136				
Ammonia-N		8.5		1.1				
Nitrate-N		13		17				

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TABLE I-8

MARLBOROUGH - PHASE III

MIXED LIQUOR - SECOND STAGE - LAST COMPARTMENT (mg/l)

Phase	IIIA															
Date	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/30	5/31	5/31	5/31	5/31	5/31	5/31
Day	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Tues	Wed	Wed	Wed	Wed	Wed	Wed
Time	7am	8am	9am	10am	11am	noon	2pm	4pm	6pm	8pm	7am	8am	9am	10am	11am	noon
Time After Shock,hrs	0	1	2	3	4	5	7	9	11	13	24/0	1	2	3	4	5
Total Solids	2600			2370				1680			1890					
Total Volatile Solids	1610			1370				980			1130					
Suspended Solids	2210			2080				1350			1430					
Volatile Susp. Solids	1480			1340				900			960					
pH	6.6			6.5				6.6			6.6					
Temperature, ^{o}C	17										17					
Alkalinity	137			107				147			185					
Dissolved Oxygen	7.3	4.3	1.8	1.2	1.2	1.0	0.5	0.8	1.0	0.3	6.2	3.5	1.5	1.2	1.5	1.3
Total Kjeldahl-N	151			129												
Ammonia-N	1.3			1.5				2.2			1.3					
Nitrate-N	**13**			**14**				**12**			**17**					
Settlometer																
5 minutes	230	190	190	190	190	180	200	190	200		210	190	190	190	200	210
10 minutes	170	140	135	140	140	140	150	150	150		155	140	140	145	150	150
15 minutes	150	120	120	120	120	120	120	120	130		140	130	120	120	130	130
20 minutes	140	120	110	110	120	110	120	110	120		130	120	110	115	120	120
25 minutes	130	115	110	110	110	110	110	110	110		125	110	110	110	110	120
30 minutes	130	110	105	110	110	105	110	110	110		120	110	110	110	110	120
40 minutes	130	110	100	100	110	100	110	110			120	110	110	110	110	110
50 minutes	120	105	100	100	100	100	110	110			120	110	100	110	110	110
60 minutes	120	105	100	100	100	100	110	100			120	110	100	110	110	110

(continued)

TABLE I-8 (continued)

Phase	IIIA														
Date	5/31	5/31	5/31	5/31	6/1	6/1	6/1	6/1	6/1	6/1	6/1	6/1	6/1	6/2	6/2
Day	Wed	Wed	Wed	Wed	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Fri	Fri
Time	2pm	4pm	6pm	10:30 pm	7am	8am	9am	10am	11am	noon	2pm	4pm	6pm	7am	9am
Time After Shock, hrs	7	9	11	15½	24	1	26	3	4	5	7	9	11	25	27
Total Solids		2460			2250							2280		2480	
Total Volatile Solids		1420			1350							1340		1510	
Suspended Solids		1930			1840							1870		1990	
Volatile Susp. Solids		1310			1200							1170		1370	
pH		6.5			6.5									6.5	
Temperature, °C					17									17	
Alkalinity		130			149									118	
Disscolved Oxygen	0.8	0.6	1.2	1.3	5.7	2.0	1.1	1.2	1.5	1.2	1.3	1.2	1.3	6.7	3.3
Total Kjeldahl-N															
Ammonia-N		2.7			1.1							3.6		0.5	
Nitrate-N		15			17							8.8		20	
Settlometer															
5 minutes	200	190	195		220	190	190	180	180	190	190	200	190	220	
10 minutes	145	145	145		160	140	135	130	130	130	145	140	140	160	
15 minutes	120	120	130		140	120	115	110	110	110	130	120	120	135	
20 minutes	120	115	120		130	120	110	105	105	105	120	110	115	135	
25 minutes	110	110	110		120	115	105	100	100	100	115	110	110	130	
30 minutes	110	110	110		120	110	105	100	100	100	110	110	110	125	
40 minutes	110	110			120	105	100	100	100	100	110	110		120	
50 minutes	105	105			120	105	100	100	100	100	110	100		120	
60 minutes	105	105			120	105	100	100	100	100	110	100		120	

(continued)

TABLE I-8 (continued)

Phase	IIIB															
Date	6/7	6/7	6/7	6/7	6/7	6/7	6/7	6/7	6/7	6/8	6/8	6/8	6/8	6/8	6/8	6/8
Day	Wed	Wed	Wed	Wed	Wed	Wed	Wed	Wed	Wed	Thur	Thur	Thur	Thur	Thur	Thur	Thur
Time	7am	8am	9am	10am	11am	noon	2pm	4pm	6pm	7am	8am	9am	10am	11am	noon	2pm
Time After Shock, hrs	0	1	2	3	4	5	7	9	11	24/0	1	2	3	4	5	7
Total Solids	2120							2280		1620						
Total Volatile Solids	1250							1880		890						
Suspended Solids	1650							2360		1200						
Volatile Susp. Solids	1130							1820		780						
pH	6.8							6.7		6.4						
Temperature, $^{\circ}C$	16									17.5						
Alkalinity	150							164		141						
Dissolved Oxygen	7.0	2.0	1.2	1.3	1.6	1.4	1.2	1.3	1.3	7.5	4.0	1.8	2.9	2.1	1.6	1.4
Total Kjeldahl-N										120						
Ammonia-N	0.9							2.2		0.8						
Nitrate-N	21							15		20						
Settlometer																
5 minutes	215	190	195	190	185	180	195	190	200	215	190	195	190	185	180	195
10 minutes	160	160	140	135	135	135	140	140	190	160	160	140	135	135	135	140
15 minutes	135	120	120	120	120	120	120	125	120	135	120	120	120	120	120	120
20 minutes	130	115	115	110	120	115	120	120	120	130	115	115	110	120	115	120
25 minutes	120	110	115	110	110	110	120	115	115	120	110	115	110	110	110	120
30 minutes	120	110	110	110	110	110	115	115	110	120	110	110	110	110	110	115
40 minutes	120	110	110	110	110	110	110	115		120	110	110	110	110	110	110
50 minutes	120	110	110	110	110	110	110	110		120	110	110	110	110	110	110
60 minutes	120	110	110	110	110	110	110	110		120	110	110	110	110	110	110

(continued)

TABLE I-8 (continued)

Phase				IIIB				
Date	6/8	6/8	6/8	6/9	6/9	6/9	6/9	6/9
Day	Thur	Thur	Thur	Fri	Fri	Fri	Fri	Fri
Time	3pm	4pm	6pm	7am	8am	9am	10am	11am
Time After Shock, hrs	8	9	11	24	25	26	27	28
Total Solids		2160		2350				
Total Volatile Solids		1210		1410				
Suspended Solids		1750		1940				
Volatile Susp. Solids		870		1320				
pH		6.7		6.4				
Temperature, ^{o}C		18		18				
Alkalinity		135		124				
Dissolved Oxygen	0.9	1.0	1.3	5.0	3.0	1.6	1.5	1.7
Total Kjeidahl-N				127				
Ammonia-N		1.7		0.9				
Nitrate-N		14		17				
Settlometer								
5 minutes		190		130				
10 minutes		140		130				
15 minutes		125		120				
20 minutes		120		120				
25 minutes		115		120				
30 minutes		115		120				
40 minutes		115		110				
50 minutes		110		110				
60 minutes		110		110				

APPENDIX J

TABLE J-1

MARLBOROUGH - PHASES I, II AND III - SLUDGES WASTED

Phase	I																
Date	**4/17**	**4/18**	**4/19**	**4/20**	**4/21**	**4/22**	**4/23**	**4/24**	**4/25**	**4/26**	**4/27**	**4/28**	**4/29**	**4/30**	**5/1**	**5/2**	**5/3**
Day	**Mon**	**Tues**	**Wed**	**Thur**	**Fri**	**Sat**	**Sun**	**Mon**	**Tues**	**Wed**	**Thur**	**Fri**	**Sat**	**Sun**	**Mon**	**Tues**	**Wed**
Sludge Wasted																	
First Stage, 10^3 liters	746	15	386	454	454	288	496	416	295	344	322	435	238	276	363	432	367
(10^3 gals)	(197)	(4)	(102)	(120)	(120)	(76)	(131)	(110)	(78)	(91)	(85)	(115)	(63)	(73)	(96)	(114)	(97)
Sludge to																	
Vacuum Filter, 10^3liters		84		105	74			110	98	83	69	73			138	95	78
(10^3 gals)		(22.1)		(27.8)	(19.6)			(29.1)	(26.0)	(22.0)	(18.1)	(19.4)			(36.5)	(25.2)	(20.5)

Phase	I				IIA					IIB					
Date	5/4	5/5	5/6	5/7	5/8	5/9	5/10	5/11	5/12	5/15	5/16	5/17	5/18	5/19	5/20
Day	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Mon	Tues	Wed	Thur	Fri	Sat
Sludge Wasted															
First Stage, 10^3 liters	405	439	432	477	454	568	341	318	318	318	318	318	318	337	348
(10^3 gals)	(107)	(116)	(114)	(126)	(120)	(150)	(90)	(84)	(84)	(84)	(84)	(84)	(84)	(89)	(92)
Sludge to															
Vacuum Filter, 10^3 liters	96	84			100	134	116	105	84	101	86	88	100	79	
(10^3 gals)	(25.4)	(22.2)			(26.4)	(35.4)	(30.7)	(27.7)	(22.3)	(26.7)	(22.8)	(23.3)	(26.4)	(20.8)	

(continued)

TABLE J-1 (continued)

Phase	IIB		IIIA						IIIB				
Date	5/21	5/22	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9
Day	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri
Sludge Wasted													
First Stage, 10^3 liters	473	428	295	273	318	341	318	318	363	318	337	295	375
(10^3 gals)	(125)	(113)	(78)	(72)	(84)	(90)	(84)	(84)	(96)	(84)	(89)	(78)	(99)
Sludge to													
Vacuum Filter, 10^3 liters		106	78	80	114	79			130	100	74	88	
(10^3 gals)		(28.0)	(20.7)	(21.2)	(30.0)	(20.9)			(34.2)	(26.3)	(19.5)	(23.2)	

TABLE J-2

MARLBOROUGH - PHASE I, II AND III

SLUDGE QUANTITIES WASTED

Phase											I										
Date	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3	5/4	5/5	5/6	5/7
Day	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun
Sludge Wasted First Stage 1000 liters	746	15	386	454	454	288	496	416	295	344	322	435	238	276	363	432	367	405	439	432	477
1000 gals	197	4	102	120	120	76	131	110	78	91	85	115	63	73	96	114	97	107	116	114	126
Sludge to Vacuum Filter 1000 liters		84		105	74			110	98	83	69	73			138	95	78	96	84		
1000 gals		22.1		27.8	19.6			29.1	26.0	22.0	18.1	19.4			36.5	25.2	20.5	25.4	22.2		

Phase			IIA						IIB				
Date	5/8	5/9	5/10	5/11	5/12	5/15	5/16	5/17	5/18	5/19	5/20	5/21	5/22
Day	Mon	Tues	Wed	Thur	Fri	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon
Sludge Wasted First Stage 1000 liters	454	568	341	318	318	318	318	318	318	337	348	473	428
1000 gals	120	150	90	84	84	84	84	84	84	89	92	125	113
Sludge to Vacuum Filter 1000 liters	100	134	116	105	84	101	86	88	100	79			106
1000 gals	26.4	35.4	30.7	27.7	22.3	26.7	22.8	23.3	26.4	20.8			28.0

(continued)

TABLE J-2 (continued)

Phase	IIIA						IIIB				
Date	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9
Day	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri
Sludge Wasted First Stage											
1000 liters	295	273	318	341	318	318	363	318	337	295	375
1000 gals	78	72	84	90	84	84	96	84	89	78	99
Sludge to Vacuum Filter											
1000 liters	78	80	114	79			130	100	74	88	
1000 gals	20.7	21.2	30.0	20.9			34.2	26.3	19.5	23.2	

TABLE J-3

MARLBOROUGH - PHASE I, II AND III - SLUDGES WASTED

Phase	IIIA				IIIB		
Date	5/30	5/31	6/1	6/2	6/7	6/8	6/9
Day	Tues	Wed	Thur	Fri	Wed	Thur	Fri
Sludge Returned to First Stage Aeration							
Total Solids	2550	2660	2740	2240	3470	3110	4290
Total Volatile Solids	1730	1770	1840	1480	2060	1810	2680
Suspended Solids	2080	2180	2280	1770	2940	2660	2870
Volatile Susp. Solids	1460	1570	1670	1370	1840	1600	2520
Total Kjeldahl-N	213			230			
Ammonia-N	23	24	24	21	28	18	14
Nitrate-N	1.0	1.5	1.0	2.1	2.0	2.0	1.0
Capillary Suction Test, sec	14.9	11.6	14.4	10.8	9.1	11.1	13.6
Return Rate, cu m/sec mgd	0.07 (1.6)	0.07 (1.6)	0.07 (1.7)	0.07 (1.8)	0.08 (1.8)	0.09 (2.0)	0.07 (1.5)
Sludge Returned to Second Stage Aeration							
Total Solids	3580	3720	3280	2080		3110	3620
Total Volatile Solids	2120	2160	2600	1180		1890	2200
Suspended Solids	3120	3340	2830	1600		2640	3150
Volatile Susp. Solids	1910	2090	2450	1040		1690	2060
Total Kjeldahl-N	210						
Ammonia-N	3.0	8.5	3.0	2.0	4.0	1.0	2.0
Nitrate-N	10	14	16	19	18	17	17
Capillary Suction Test,sec	5.9	7.3	5.7	6.4	5.3	5.7	5.7
Return Rate, cu m/sec mgd	0.09 (2.1)	0.09 (2.0)	0.11 (2.4)	0.11 (2.4)	0.07 (1.5)	0.07 (1.6)	0.09 (2.0)

TABLE J-4

VARIATION OF SOLIDS CONCENTRATION WITH DEPTH IN THE PRIMARY CLARIFIER DURING SHOCK LOADING - PHASE III

TOTAL SOLIDS (mg/l)

Phase IIIB

Date 6/8

Time	Top (1 ft. below surface)	Middle (5 ft. below surface)	Bottom (10 ft. below surface)	Effluent (in trough)
7 am Shock	544	532	386	470
7:30 am	436	544	1204	476
8 am	482	914	1088	668
8:30 am	707	962	1506	962
9 am	870	892	996	970
10 am	728	848	956	842
11 am				918
12 noon	672	668	732	722
2 pm Shock			1436	806
2:15 pm	700	716	838	
3:15 pm	682	704		
4 pm				598
6 pm				490

TOTAL VOLATILE SOLIDS (mg/l)

Time	Top (1 ft. below surface)	Middle (5 ft. below surface)	Bottom (10 ft. below surface)	Effluent (in trough)
7 am Shock	142	136	86	230
7:30 am	110	188	690	238
8 am	176	452	610	420
8:30 am	364	422	842	600
9 am	360	384	456	588
10 am	252	406	468	526
11 am				452
12 noon	272	222	292	316
2 pm Shock				332
2:15 pm	192	206	700	
3:15 pm	200	264	264	
4 pm				142
[illegible] pm				166

APPENDIX K

TABLE K-1

UNIVERSITY OF LOWELL PILOT PLANT - CONVENTIONAL MODE OF OPERATION - PHASE I

INFLUENT (mg/l)

Date	3/12	3/13	3/14	3/15	3/16	3/17	3/18	3/19	3/20	3/21	3/22	3/23	3/24	3/25	3/26	3/27	3/28
Day	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues
Flow Rate, gpd	30400	28800	28800	26600	27900	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	34600	33100
COD-Total	467	356	286	217	316	257	87	107	125	136	128	108	102	129	282	214	174
COD-Soluble									55								
BOD-N Suppressed									95	66			57				59
Total Solids	616	514	450	384	560	706	574	402	380	376	400	410		380	434	380	368
Total Volatile Solids	316	274	188	122	190	182	192	108	116	166	176	106		70	176	150	92
Suspended Solids	90	126	173	82	358	156	108	60	49		43	68		18	152	105	85
Volatile Susp. Solids	76	122	143	67	192	102	84	32	48		38			11	126	87	62
Total Kjeldahl-N	30.5		22.7		24.2			11.5		8.3		10.1			17.9		19.3
Ammonia-N	8.0	7.5	12.0	12.0	14.0	17.0	8.9	4.3	4.8	4.0	4.2	4.3	4.3	7.0	8.1	6.5	11.0
Nitrate-N	1.5	1.6	1.4	0.8	1.0	1.0	1.0	1.1	0.8	1.5	0.9	2.6	2.2	1.6	1.2	1.5	1.5
Total Phosphorous		18		8.0					4.5		3.5					2.5	
Alkalinity	88	118	89	97	128	116	127	97	108	61	129	124	110	118	92	103	133
pH	7.2	7.1	7.0	6.6	6.8	6.6	6.7	6.8	6.6	6.9	6.8	6.7	6.5	6.8	6.8	6.6	7.2
Temperature, ^{o}C		15	16	14	17	14			13	13	12	14	13			6	15
Dissolved Oxygen		7.4	6.6	8.5	6.9	7.6			8.4	7.6	9.8	8.4	7.6			8.0	7.5

TABLE K-2

UNIVERSITY OF LOWELL PILOT PLANT - CONVENTIONAL MODE OF OPERATION-PHASE I

SECONDARY EFFLUENT (mg/1)

Date	3/12	3/13	3/14	3/15	3/16	3/17	3/18	3/19	3/20	3/21	3/22	3/23	3/24	3/25	3/26	3/27	3/28
Day	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues
COD-Total	73	54	53	57	53	56		32	43	35	54	31	31	43	31	31	116
COD-Soluble					61			24	43	31	43	31				31	47
BOD-N Suppressed									5.5	3.5			3.0				
Total Solids	430	350	320	334	500	580		402	346	302	338	408	344		304	277	450
Total Volatile Solids	112	138	86	80	142	70		96	76	100	130	102	56		42	86	140
Suspended Solids	21	7	16	9	3	2		12	5	3	4	13	9		8	12	85
Volatile Susp. Solids	14	1	15	5	2	0		5	4	3	4		8		5	12	62
Total Kjeldahl-N	3.6		8.1		9.6			2.4		1.3					1.4		8.7
Ammonia-N	2.3	2.1	6.0	9.0	8.2	3.2		0.0	0.0	0.2	.1	.1	.1	.1	.1	1.0	2.0
Nitrate-N	12.0	12.5	6.5	7.4	5.5	7.5		9.8	8.0	7.5	8.5	7.5	7.3	8.0	9.0	10	12
Total Phosphorous		2.1		2.8					1.9		2.1					1.6	
Alkalinity	18	28	52	83	95	61		61	61	95	70	75	88	62	56	53	62
pH	6.7	6.5	6.6	6.9	7.0	6.8		6.7	6.8	6.8	6.8	6.8	6.6	6.3	6.5	6.7	6.8
Temperature, $^{\circ}C$		12	11	11	12	12			10	10	10	10	10			9	11
Dissolved Oxygen			3.5	2.3	0.8	0.4			1.9	2.1	4.8	4.3	4.8			5.8	1.9

TABLE K-3

UNIVERSITY OF LOWELL PILOT PLANT - CONVENTIONAL MODE OF OPERATION

PHASE I - MIXED LIQUOR (mg/l)

Date	3/13	3/14	3/15	3/16	3/17	3/20	3/21	3/22	3/23	3/24	3/25	3/26	3/27	3/28
Day	Mon	Tues	Wed	Thur	Fri	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues
Total Solids	2100	2150	2040	2300	2428	2618	2518	2766	2622	2392			2692	2608
Total Volatile Solids	1460	1590	1430	1660	1658	1824	1730	2004	1842				1898	1846
Suspended Solids	2280	1970	3090	2370	1950	2560	2490		2520	2360	2380	2540	2575	2470
Volatile Susp. Solids	1780	1590	2610	1830	1500	1880	1930		2030		1780	1910	1930	1950
Alkalinity	49	48	74	100	106	96	94	78	104	101			91	106
pH	6.8	6.6	6.6	6.8	6.7	6.6	6.5	6.6	6.7	6.5			6.6	6.7
Temperature, ^{o}C	12	12	12	12	12	11	11	11	12	12			9	12
D.O.Uptake, mg/l-hr	26	18	63	40	19	23	22	20	29	20			30	37
Dissolved Oxygen, mg/l														
Location A nr. Surface	6.0	5.8	2.8	3.7	2.7	2.7	2.1	4.9	3.1	3.3			2.6	0.8
A nr. Bottom	5.8	5.5	2.6	3.4	2.6	2.6	2.1	4.6	2.7	3.2			2.6	0.7
B nr. Surface	5.9	5.5	2.5	3.9	2.7	2.8	2.3	4.5	2.7	2.9			6.1	0.8
B nr. Bottom	5.8	5.2	2.4	3.4	2.5	2.6	1.8	4.4	2.5	2.7			6.1	0.8
C nr. Surface	6.8	6.9	4.6	1.6	0.8	4.8	4.2	7.2	6.1	6.0			7.1	3.3
C nr. Bottom	6.7	6.7	4.6	1.0	0.5	4.9	4.1	6.7	5.9	5.8			7.1	3.2
Total Kjeldahl-N	171		146		168	182		193		171			171	
Ammonia-N	3.1	2.5	8.0	9.0	8.8	0.0	0.7	0.2	0.2	0.2			0.1	2.5
Nitrate-N	11	13	5.8	7.0	6.5	9.8	8.5	8.5	9.5	8.8			9.8	9.0
Settlometer														
5 minutes	960	960	950	960	960	980	980	960	950	950			900	900
10 minutes	910	900	870	910	920	950	910	910	900	860			800	810
15 minutes	840	850	780	850	880	900		860	840	770			710	740
20 minutes	780	780	710	790	840	860	810	800	780	730			650	670
25 minutes	700	720	670	740	780	830	770	740	730	680			600	600
30 minutes	650	660	620	680	740	790	730	700	680	630			560	550
45 minutes		540	500	570	610	670	600	560	570	520			480	450
60 minutes	460	460	440	480	540	590	540	500	490	460			430	400

APPENDIX L

TABLE L-1

UNIVERSITY OF LOWELL PILOT PLANT - CONVENTIONAL MODE OF OPERATION

PHASE II - SEPTAGE (mg/l)

Date	3/29	3/30	3/31	4/1	4/2	4/3	4/4	4/5	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17
Day	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon
Septage Volume, gpd	123	194	110	137	0	132	194	123	106	115	97	106	264	247	216	203		159	229	
% of Daily Flow	0.43	0.62	0.38	0.48	0	0.46	0.67	0.43	0.41	0.40	0.34	0.37	0.92	0.96	0.78	0.67		0.69	0.86	
COD-Total	22090	10080	16800			33010	33780	5620	5300	6270	1880	1600	1310	17760	11220	8590	45490	34630	11480	11280
BOD-N Suppressed	4500		3900				5320						660		1950					
Total Solids	6810	5720	6690	3680			3780	3462	3530	2740	1480	1290	970	17260	3960	4530	41770	5960	6100	6670
Total Volatile Solids	5140	4720	5510	3060			2720	2600	2720	2120	970	820	500	12070	3020	3570	29410	4840	5140	5340
Suspended Solids	1800	1780	1850	2510			950	2310	2640	1950	990	780	480	15720	2760	3060	39230	3900	4170	4910
Volatile Susp. Solids	570	1290	1100	2420			330	1760	2130	1660	760	520	320	11040	2270	2520	28830	3360	3740	4040
Total Kjeldahl-N	448		342					246		280			109		263		666			426
Ammonia-N	145	105	46				116	75	60	54	27	27	24	110	80	68	1.6	213	188	138
Total Phosphorus			80				96		86					123		102				
Alkalinity	650	210	250				276	334	269		259	245		613	566	273	1332	760	706	500
pH	7.1	7.2	7.6				6.8	7.2	7.4		7.1	7.2	7.3	6.1	7.0	6.8	6.1	6.3	6.6	7.3
Nitrate-N													0.8				0.0			

TABLE L-2

UNIVERSITY OF LOWELL PILOT PLANT - CONVENTIONAL MODE OF OPERATION

PHASE II - INFLUENT (mg/l)

Date	3/29	3/30	3/31	4/3	4/4	4/5	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17
Day	Wed	Thur	Fri	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon
Flow Rate, gpd	28800	31400	28800	28800	28800	28800	25600	28800	28800	28800	28800	25600	27600	30100	28800	23000	26600	
COD-Total	170	218	239	227	248	216	200	168	379	468	324	295	176	192	191	82	436	
COD-Soluble																		
BOD-N Suppressed		170		99						149		71						
Total Solids	478	336	466	488	458	402	414	442	498	620	456	388	486	392	450	336	482	
Total Volatile Solids	138	94	192	194	240	202	160	158	230	296	186	136	218	110	140	118	216	
Suspended Solids		45	50	62	78	74	62	61	83	186	102	84	72	54	50	10	92	
Volatile Susp. Solids		42	37	54	72	64	60	54	69	168	86	68	68	50	40	6	76	
Total Kjeldahl-N		22.4			22.4		23.8					21.8		18.5			30.8	
Ammonia-N	10	13		13	14.5	15	11.5	11	12	6.0	22	8.0	10	20	9.5	11	10	
Nitrate-N	1.3	1.2		1.0	0.9	0.7	1.0	1.4	1.5	2.0	4.5	3.5	2.7	3.5	0.7	0.8	1.8	
Total Phosphorus		4.1		8.0		4.8					4.3		4.0					
Alkalinity	125	136		150	138	138	143	140	132	115	140	104	127	85	142	130	105	
pH	6.8	7.3		6.9	6.8	6.8	8.6	6.6	6.7	6.7	6.8	6.6	6.8	5.8	6.7	6.6	6.8	
Temperature, ^{o}C	15	15		16	15	16	17				17	17	16	18	18	12	15	16
Dissolved Oxygen	7.2	6.6		6.3	6.7	6.3	5.9				5.4	5.2	5.9	5.4	5.8	7.6	4.4	5.0

TABLE L-3

UNIVERSITY OF LOWELL PILOT PLANT - CONVENTIONAL MODE OF OPERATION - PHASE II

EFFLUENT (mg/l)

Date	3/29	3/30	3/31	4/3	4/4	4/5	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17
Day	Wed	Thur	Fri	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun	
Septage/Sewage, %	0.43	0.62	0.38	0.46	0.67	0.43	0.41	0.40	0.34	0.37	0.92	0.96	0.78	0.67		0.69	0.86	
COD-Total	23.7	35.7	46.3	38.6	34.9	31.5	27.5	19.5	19.5	23.4	34.7	47.2	31.2	78.4	230	31.1	432	
COD-Soluble	19.8	27.8		30.9	15.5	27.6	15.7			19.5	27.0	23.6	27.3	27.5	31.1	19.5	13.3	
BOD-N Suppressed		6.6		1.7						1.7		3.7						
Total Solids	460	316	380	368	338	316	342	330	360	358	382	314	358	342	542	336	598	
Total Volatile Solids	116	58	64	126	112	130	90	72	82	68	96	54	86	78	208	86	304	
Suspended Solids	10	1	4	2	4	10	3	1	4	2	12	11	7	28	68	1	238	
Volatile Susp. Solids	8	1		2	4	9	3	1	2	2	9	9	7	26	62	1	222	
Total Kjeldahl-N		2.5			2.0		1.7			1.5		2.7		4.3				
Ammonia-N	1.3	1.8		1.2	1.4	1.3	1.2	1.1	1.8	0.8	1.5	1.2	1.4	0.8	2.9	2.0	1.3	
Nitrate-N	11.0	10.0		9.5	9.5	7.5	7.8	8.5	12.0	10.5	7.5	8.0	5.0	4.4	2.6	6.0	5.0	
Total Phosphorus		2.0		2.9		2.7					2.9		2.9					
Alkalinity	54	61		68	65	74	69	54	61	64	71	65	65	60		75	99	
pH	6.7	7.2		6.8	6.8	6.6	6.7	6.3	6.7	6.7	6.6	6.6	6.6	6.5		6.7	6.8	
Temperature, °C	12	12	13		12	12	13	13			14	13	14	14	14	13	12	13
Dissolved Oxygen	0.9	0.9	0.3		0.3	0.3	0.2	0.3			0.2	0.4	0.3	0.1	0.2	1.6	0.3	0.3

TABLE L-4

UNIVERSITY OF LOWELL PILOT PLANT - CONVENTIONAL MODE OF OPERATION - PHASE II

MIXED LIQUOR (mg/1)

Date	3/29	3/30	3/31	4/4	4/5	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/16	4/17
Day	Wed	Thur	Fri	Tues	Wed	Thur	Fri	Sat	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Sun @9am	Sun @5pm	Mon
Total Solids	2610	2800	2630	3680	3380	3420	3730	3350	3510	3440	3458	3812	3300	3230	3036	2732		2536
Total Volatile Solids	1820	1930	1890	2800	2650	2660	2860	2730	2660	2620	2695	2956	2560	2490	2262	2082		1926
Suspended Solids	1740	2950	2930	3480	3510	3080	3280	2760	3340	3040	3140	3526	2950	2930	2582	2544		2266
Volatile Susp. Solids	1350	2260	2380	2780	2890	2540	2710	2060	2700	2500	2617	2924	2470	2220	2158	1866		1890
Alkalinity	110	130	112	157	127	139	29	168	190	100	101	145	141	185	161	187		138
pH	6.8	6.6	6.6	6.8	6.7	6.7	6.0	6.2	6.4	6.2	6.2	6.7	6.4	6.7	6.4	6.5		6.5
Temperature, ^{O}C	13	13	13	13	13	14	14			14	14	14	15	15	15	14		14
D.O. Uptake, mg/l-hr	32	36	38	41	27	48	31			24	67	27	55					
Dissolved Oxygen																		
Location A nr. surface	0.6	0.9	1.0	1.0	1.8	0.9	1.4			0.9	0.7	2.0	0.7	0.8	7.6	1.5	4.8	2.4
A nr. bottom	0.5	0.7	0.6	0.7	1.1	0.9	1.2			0.8	0.5	1.8	0.6	0.7	7.4	0.9	4.8	2.2
B nr. surface	0.6	0.8	0.8	0.9	1.4	1.1	1.4			1.1	1.0	2.2	0.8	0.8	7.4	0.6	4.8	2.1
B nr. bottom	0.4	0.7	0.7	0.8	1.3	1.2	1.2			0.9	0.8	2.2	0.7	0.6	7.3	0.2	4.5	2.1
C nr surface	2.3	4.1	0.6	0.5	0.4	0.3	0.4			0.2	0.8	0.4	0.2	0.4	4.0	0.3	1.4	0.6
C nr. bottom	1.9	3.5	0.5	0.3	0.4	0.3	0.3			0.2	0.4	0.3	0.2	0.2	3.9	0.2	1.0	0.3
Total Kjeldahl-N	196		224		252		288			244		246		190				202
Ammonia-N	2.2	1.4	3.6	1.5	2.5	1.5	2.8	3.7	2.1	3.6	1.6	2.0	1.5	1.3	5.0	3.2		0.5
Nitrate-N	11.0	10.0	8.0	9.5	6.5	5.8	8.5	0.9	1.2	2.9	7.5	4.0	4.2	1.9	0.8	2.2		5.5
Settlometer																		
5 minutes	880	940	910	950	970	980	980				990							
10 minutes	790	850	810	900	920	940	950			980	950	980		980				950
15 minutes	700	780	730	850	870	910	920			950	920	960		950				910
20 minutes	620	710	680	820	830	870	880			930	900	940		930				880
25 minutes		650	620	790	790	840				900	880	920		900				850
30 minutes	510	590	580	740	750	810	830			880	860	900		880				820
45 minutes	420	480	470	620	640	680	700			780	800	850		820				750
60 minutes	390	420	420	540	570	610	650			730	740	800		760				680

APPENDIX M

TABLE M-1

UNIVERSITY OF LOWELL PILOT PLANT - CONVENTIONAL MODE OF OPERATION - PHASE III

SEPTAGE (mg/l)

Date	5/3	5/4	5/5	5/18	5/19
Day	Wed	Thur	Fri	Thur	Fri
Volume, gal	300	300	300	600	450
Loading Time	8am	8am	8am	8am	9am
COD-Total	10395	14570	45800	26587	11111
BOD-Total	1200	2035	9600	6188	
BOD-N Suppressed		2030	8775	6188	
Total Solids	5888	4440	12824	6198	4672
Total Volatile Solids	4688	3504	10580	4802	3428
Suspended Solids	4522	2976	11132	4364	2978
Volatile Susp. Solids	3820	2584	9416	3554	2430
Total Kjeldahl-N	367	357	974	661	319
Ammonia-N		170	360	120	
Total Phosphorous	78	52	370	187.5	475
pH	6.19	6.23	5.81	5.58	5.78
Alkalinity	896	790	1580	490	310
% of Flow	1.04	1.04	1.04	2.08	1.56

TABLE M-2

UNIVERSITY OF LOWELL PILOT PLANT - CONVENTIONAL MODE OF OPERATION - PHASE III

INFLUENT (mg/l)

Date	5/3	5/4	5/5	5/6	5/7	5/18	5/19	5/20	5/21
Day	Wed	Thur	Fri	Sat	Sun	Thur	Fri	Sat	Sun
Flow Rate, gpm	20	20	20	20	20				
COD-Total	600	219	428	266		177	274	211	163
COD-Soluble	138	106	80	48		79	91	76	
BOD-Total	154	89	90	118		97		76	91
BOD-N Suppressed	121	61	86	90		90		38	58
Total Solids	440	390	516	486		404	420	358	340
Total Volatile Solids	190	144	326	254		154	126	108	170
Suspended Solids	118	31	103	118		92	90	78	28
Volatile Susp. Solids	110	27	102	110		72	62	66	18
Total Kjeldahl-N	26.6	24.9	33.9	24.6		18.8	30.0	22.1	19.3
Ammonia-N	16.5	15.0	16.0	14.0	12.0		17.0	8.5	15.0
Nitrate-N	0.44	1.00	0.50	1.05	0.90	3.0	0.85	0.75	1.0
Total Phosphorous			6.75	4.0		1.8	5.3	4.3	4.2
pH	6.5	6.88	7.02	7.15		6.74	6.90	6.84	6.70
Temperature, $^{\circ}$C	19.0	19.5	19.0	15.0	17.0	18.0	17.0	17.0	20.0
Alkalinity	148	137	148	129	130	106	138	140	152

TABLE M-3

UNIVERSITY OF LOWELL PILOT PLANT - CONVENTIONAL MODE OF OPERATION

PHASE III - EFFLUENT (mg/l)

Date	5/3	5/3	5/3	5/3	5/3	5/3	5/4	5/4	5/4	5/4	5/4	5/4	5/5	5/5	5/5	5/5	5/5	5/5	5/6
Day	Wed	Wed	Wed	Wed	Wed	Wed	Thur	Thur	Thur	Thur	Thur	Thur	Fri	Fri	Fri	Fri	Fri	Fri	Sat
Time	8am	9am	10am	11am	noon	2pm	8am	9am	10am	11am	noon	2pm	8am	9am	10am	11am	noon	2pm	8am
Time After Shock, hrs	0	1	2	3	4	6	24/0	1	2	3	4	6	24/0	1	2	3	4	6	24
COD-Total		51	87	59	79	121	51	47	47	1272	1272	1040	116	16	68	52	416	1240	369
COD-Soluble	32	36	35	28	20	24	23	39	39	43	39	63	24	12	24	40	20	24	32
BOD-Total		10	19	20	22	20	9	4	6	503	945	485	112	74	62	22	21	443	165
BOD-N Suppressed		6	12	11	15	18	1	1	1	203	180	128	14	8	40	10	12	375	47
Total Solids	Comp 400	294	308	330	340	398	288	252	306	992	1194	882	472	372	298	306	288	1202	450
Total Volatile Solids	Comp 174	126	162	160	154	206	112	92	84	630	876	566	198	174	94	130	92	884	218
Suspended Solids	Comp 114	4	15	11	40	60	15	1.5	3	640	896	800	136	56	25	12	16	872	232
Volatile Susp. Solids	Comp 104	3	13	10	37	56	13	0.5	1	592	768	708	108	46	3	10	8	700	198
Total Kjeldahl-N	9.8	2.9	9.4	10.4	11.6	10.6	1.5	1.0	4.6	71.7	74.5	56.6	13.0	8.7	6.4	8.8	40.0	58.2	22.7
Ammonia-N	0.26	1.45	5.00	8.50	7.50	6.00	0.45	0.24	2.20	4.90	5.00	5.25	2.2	1.1	2.0	3.2	2.8	7.1	6.0
Nitrate-N	9.00	7.50	5.00	3.00	2.40	2.00	1.80	1.60	1.00	0.65	0.85	0.70	1.70	2.50	0.78	0.55	0.80	0.62	0.95
Total Phosphorous							0.6	0.8	1.8	15.5	18.5		13.0	1.3	4.3	10.3	4.0	16.5	4.3
pH	6.75	6.80	6.97	7.18	7.06	6.73	7.04	7.02	7.06	6.98	7.02	6.90	6.72	6.76	6.91	6.88	7.00	6.77	7.12
Temperature, ^{o}C	14	15	15		16	17	15	15.5	17	15.5	16	17	16	16	16	15.5	15.5	16	15
Alkalinity	67	77	96	104	104	104	97	89	99	129	121	122	93	87	98	91	108	116	105

(continued)

TABLE M-3 (continued)

Date	5/18	5/18	5/18	5/18	5/18	5/18	5/19	5/19	5/19	5/19	5/19	5/19	5/20	5/21
Day	Thur	Thur	Thur	Thur	Thur	Thur	Fri	Fri	Fri	Fri	Fri	Fri	Sat	Sun
Time	8am	9am	10am	11am	noon	2pm	7am	10am	11am	noon	1pm	3pm	8am	8am
Time After Shock, hrs	0	1	2	3	4	6	23/0	1	2	3	4	6	23	47
COD-Total	83	551	976	658	390	389	123	643	1659	921	246	389	622	219
COD-Soluble	59	39	51	51	51	83	44	64	95	52	64	60	56	32
BOD-Total	75	285	390	336	258	426	52	300	540	413	323	188	180	
BOD-N Suppressed	28	123	171	204	147	198	20	120	158	150	68		113	165
Total Solids	398	832	1052	726	516	462	390	846	836	870	758	558	768	520
Total Volatile Solids	130	462	468	400	262	198	58	452	468	504	412	238	410	342
Suspended Solids	52	264	816	371	212	416	66	500	513	513	413	252	432	248
Volatile Susp. Solids	46	188	392	300	168	184	44	352	373	387	307	184	66	224
Total Kjeldahl-N	14.6	41.4	42.6	33.6	28.6	34.7	13.3	19.6	25.5	21.8	15.4	15.4	36.1	98
Ammonia-N	10.0	9.0	11.5	14.0	13.5	12.5	11.0	14.5	20.0	16.0	18.0	15.0	14.0	
Nitrate-N	5.0	2.0	1.4	0.95	0.95	1.0	1.50	0.90	0.95	0.70	0.65	0.85	0.95	
Total Phosphorous	4.0	7.5	10.5	7.8	9.5	6.5	1.0	7.0	12.0	8.3	11.3	5.0	7.3	4.5
pH	6.80	6.96	6.77	6.90	6.90		6.86	6.60	6.80	6.87	6.92	6.78	6.80	6.70
Temperature, ^{o}C	16.0	16.0			17.0	17.0	16.0	17.0	18.0	18.0		19.0	17.0	18.0
Alkalinity	102	106	120	132	127		119	133	150	153	146	141	134	129

TABLE M-4

UNIVERSITY OF LOWELL PILOT PLANT - CONVENTIONAL MODE OF OPERATION - PHASE III

MIXED LIQUOR (mg/l)

Date	5/2	5/3	5/3	5/3	5/3	5/3	5/3	5/4	5/4	5/4	5/4	5/4	5/4	5/5	5/5	5/5	5/5	5/5	5/5
Day	Tues	Wed	Wed	Wed	Wed	Wed	Wed	Thur	Thur	Thur	Thur	Thur	Thur	Fri	Fri	Fri	Fri	Fri	Fri
Time	8am	8am	9am	10am	11am	noon	2pm	8am	9am	10am	11am	noon	2pm	8am	9am	10am	11am	noon	2pm
Total Solids	2020	1672	2120	1892				1984						1564					
Total Volatile Solids	1542	1266	1630	1460				1424						1208					
Suspended Solids	1670	1414	1840	1616				1636						1268					
Volatile Susp. Solids	1420	1218	1556	1396				1268						1068					
pH		6.50						6.82	7.07	6.97	6.89	6.94	6.72	6.55	6.80	6.88	6.80	6.78	
Temperature, °C		15.0	16.0	16.0		16.0	16.5	15.5	15.5	16.0	16.0	17.0	17.0	16.0	16.0	16.0	16.0	16.0	16.0
Alkalinity		105						122	126	128	124	132	156	112	144	151	144	140	129
D.O. Uptake, mg/l-hr.		8.2	17.9	25.5	29.8	37.6	41.4	9.0	28.0	27.3	29.9	39.1	41.5	19.9	30.8	28.4	31.2	34.8	33.2
Settlometer																			
5 minutes		980	970	970	970	980	990		1000	1000	1000	990	980	970	970	970	970	970	970
10 minutes		950	940	950	970	950	950	990	970	970	970	950	950	950	930	940	940	950	940
15 minutes		870	910	890	920	920	890	980	950	950	950	930	900	930	890	910	910	930	910
20 minutes		760	850	840	890	890	820	950	920	930	940		830	900		870	870	900	880
25 minutes		710	800	760	870	850	750	930	900	890	900	830	770	880	830	850	850	870	850
30 minutes		680	750	710	830	810	700	900	860	870	880	780	730	830	780	820	830	850	820
45 minutes		570	640	600	700	710	600	830	780	800	790	680	640	750	680	730	740	780	740
60 minutes		510	550	540	640	680		750	710	730	710	600	550	690	620	650	680	720	610

(continued)

TABLE M-4 (continued)

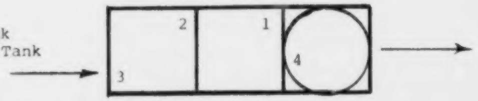
Date	5/6	5/7	5/17	5/18	5/18	5/18	5/18	5/18	5/18	5/19	5/19	5/19	5/19	5/19	5/19	5/20	5/21
Day	Sat	Sun	Wed	Thur	Thur	Thur	Thur	Thur	Thur	Fri	Fri	Fri	Fri	Fri	Fri	Sat	Sun
Time	8am	8am	8am	8am	9am	10am	11am	noon	2pm	7am	10am	11am	noon	1pm	3pm	7am	9am
Total Solids	1540	1894	1198	1086	1934		1950		1628	1318	846	836	870	758	558	1468	1156
Total Volatile Solids	1128	1080	816	696	1434		1450		1192	886	452	468	504	412	238	996	906
Suspended Solids	1240	1526	932	742	1540		1608		1286	992	500	513	513	413	252	1164	906
Volatile Susp. Solids	958	1042	700	612	1256		1366		1022	846	352	373	387	307	184	956	780
pH			6.60	6.66	6.78	6.90	7.04	6.90		6.89	6.67	6.61	6.59	6.74	7.45	6.77	6.67
Temperature, °C	15.0	16.0		16.0	16.0			17.0	18.0	16.0	17.0	18.0	18.0		19.0	18.0	18.0
Alkalinity	109		91	119	144	142	149	144		147	160	164	153	160	189	137	140
D.O. Uptake, mg/l-hr	18.1	12.0		12.3	28.7	24.5	22.4	22.1	23.5	14.7	47.5	51.2	40.6	51.9	58.8	21.2	20.6
Settlometer																	
5 minutes	950	980		970		960	960	920	940	940	960	940	880	890	890	930	910
10 minutes	900	960		920	850	870	870	830	880	850	880	820	750	740	740	730	720
15 minutes	860	950		880	770	770	770	700	790	760	730	700	640	650	660	610	600
20 minutes	820	920		830	670	650	650	650	750	690	660	640	580	580	580	540	530
25 minutes	760	900		770	620	600	610	600	690	620	610	580	540	520	520	500	480
30 minutes	720	870		710	560	560	580	560	620	580	580	540	490	480	490	460	440
45 minutes	620	800		620	480	460	460	450	520	490	490	450	400	400		390	380
60 minutes	530	730		550	410	400	410	410	450	420	420	390	350	350		340	330

TABLE M-5

UNIVERSITY OF LOWELL PILOT PLANT - CONVENTIONAL MODE OF OPERATION - PHASE III

DISSOLVED OXYGEN (mg/l)

A - Top of Tank
B - Bottom of Tank



Date		5/3		5/3	5/3	5/3	5/3	5/3	5/4		5/4	5/4	5/4	5/4	5/4
Day		Wed		Wed	Wed	Wed	Wed	Wed	Thur		Thur	Thur	Thur	Thur	Thur
Time		7:50 am		9am	10am	11am	noon	2pm	7:50 am		9am	10am	11am	noon	2pm
Time after shock, hrs.		Before		1.0	2.0	3.0	4.0	6.0	Before		1.0	2.0	3.0	4.0	6.0
Point	3A	7.6	Shock @ 8:00 am	3.3	4.2	4.6	4.6	4.3	6.8	Shock @ 8:00 am	2.2	3.4	4.6	4.8	4.6
	3B	6.6		3.1	3.9	4.2	4.2	4.3	6.4		2.2	3.5	4.6	4.8	4.6
	2A	6.6		2.9	3.9	4.5	4.5	4.1	6.2		1.9	3.6	4.4	4.4	4.2
	2B	6.2		2.8	3.8	4.0	4.5	4.1	5.8		2.0	3.6	4.2	4.6	4.2
	1A	4.9		0.8	1.2	0.8	1.0	0.9	2.8		0.4	0.6	1.2	0.7	0.8
	1B	4.4		0.8	0.8	0.8	0.8	0.8	2.8		0.5	0.4	0.5	0.6	0.5
	4A	1.0		0.4	0.4	0.2	0.3	0.3	1.0		0.1	0.0	0.0	0.0	0.0

Date		5/5		5/5	5/5	5/5	5/5	5/5	5/6	5/7
Day		Fri		Fri	Fri	Fri	Fri	Fri	Sat	Sun
Time		7:50 am		9am	10am	11am	noon	2pm	8am	8am
Time after shock, hrs.		Before		1.0	2.0	3.0	4.0	6.0	No Shock	No Shock
Point	3A	6.9	Shock @ 8:00 am	1.9	4.2	5.6	5.4	4.4	8.0	7.4
	3B	6.4		1.9	3.9	5.4	5.2	4.4	7.5	7.3
	2A	6.4		2.0	4.6	5.7	5.3	4.6	8.2	7.8
	2B	5.4		1.9	4.2	5.6	5.2	4.4	6.0	7.4
	1A	2.8		0.3	0.5	0.8	1.4	1.0	3.4	5.2
	1B	1.6		0.2	0.4	0.5	0.8	0.6	2.2	4.0
	4A	0.3		0.0	0.0	0.0	0.2	0.0	0.3	0.4

(continued)

TABLE M-5 (continued)

Date		5/18		5/18	5/18	5/18	5/18	5/18	5/19		5/19	5/19	5/19	5/19	5/19	5/20	5/21
Day		Thur		Thur	Thur	Thur	Thur	Thur	Fri		Fri	Fri	Fri	Fri	Fri	Sat	Sun
Time		7am		9am	10am	11am	noon	2pm	7am		10am	11am	noon	1pm	3pm	7am	9am
Time after shock, hrs.		Before		1.0	2.0	3.0	4.0	6.0	Before		1.0	2.0	3.0	4.0	6.0	No Shock	No Shock
Point	3A	6.2	Shock @ 8:00 am	0.6	0.4	0.6	1.2	0.4	3.9	Shock begun @ 9:00 am Completed @ 9:50 am	0.4	0.4	0.5	0.4	0.7	3.9	3.3
	3B	6.0		0.5	0.4	0.6	1.0	0.2	3.7		0.4	0.3	0.4	0.4	0.6	3.7	3.1
	2A	6.3		0.6	0.4	0.6	1.2	0.2	3.4		0.4	0.4	0.4	0.3	0.4	3.5	2.9
	2B	6.1		0.5	0.4	0.6	1.0	0.2	3.4		0.3	0.3	0.3	0.2	0.4	3.4	2.9
	1A	8.0		1.9	2.2	3.8	3.8	3.2	6.8		0.4	0.4	1.2	1.5	1.1	6.9	7.2
	1B	8.0		1.9	2.3	3.7	3.8	3.2	6.8		0.4	0.4	1.1	1.5	1.0	6.8	7.2
	4A	1.2		0.2	0.0	0.0	0.1	0.5	0.5		0.1	0.0	0.2	0.2	0.3	1.0	1.3

APPENDIX - N

TABLE N-1

UNIVERSITY OF LOWELL PILOT PLANT - OPERATION IN EXTENDED AERATION MODE - PHASE III

SEPTAGE (mg/l)

Phase	IIIA					IIIB				
Date	7/25	7/26	7/27	7/28	7/29	8/1	8/2	8/3	8/4	8/5
Day	Mon	Tues	Wed	Thur	Fri	Mon	Tues	Wed	Thur	Fri
Total Volume, liters	401	401	401	0	0	795	795	795	0	0
(gallons)	(106)	(106)	(106)	(0)	(0)	(210)	(210)	(210)	(0)	(0)
% Daily Flow	1.33	1.33	1.33			2.63	2.63	2.63		
COD-Total	19200	25280	46400			62450	40800	7370		
Total Solids	9210	13540	29390			34390	11770	4100		
Total Volatile Solids	7400	9500				29200	9730	3340		
Suspended Solids	9400	17800	28750			29000	6000	2200		
Volatile Susp. Solids	6400		22240			27750	6000	1600		
Total Kjeldahl-N	487	683	728			1025	381	241		
pH	6.2	5.4	5.5			6.9	6.8	6.9		
Grease	17700	23720	8500							
Total Phosphorous	250	275	275			120	60	52		

TABLE N-2

UNIVERSITY OF LOWELL PILOT PLANT - OPERATION IN EXTENDED AERATION MODE - PHASE III

INFLUENT (mg/l)

Phase	IIIA					IIIB				
Date	7/25	7/26	7/27	7/28	7/29	8/1	8/2	8/3	8/4	8/5
Day	Mon	Tues	Wed	Thur	Fri	Mon	Tues	Wed	Thur	Fri
Flow, liters per day	30280	30280	30280	30280	30280	30280	30280	30280	30280	30280
gallons per day	(8000)	(8000)	(8000)	(8000)	(8000)	(8000)	(8000)	(8000)	(8000)	(8000)
COD-Total	56	112	127	175	323	216	100	107		211
Suspended Solids	23	31	33	53	63	104	32	46		58
Volatile Suspended Solids		29	16			100		35		49
Total Kjeldahl-N	5.0	8.1	11.5			20.4	10.1	10.9		
Total Phosphorous		6.5				3.9	0.6	1.6		

TABLE N-3

UNIVERSITY OF LOWELL PILOT PLANT - OPERATION IN EXTENDED AERATION MODE - PHASE III

EFFLUENT (mg/l)

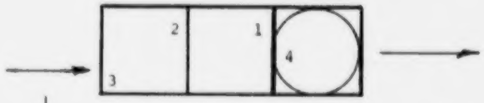
Phase	Shock						IIIA Shock						Shock							
Date	7/25	7/25	7/25	7/25	7/25	7/25	7/26	7/26	7/26	7/26	7/26	7/26	7/27	7/27	7/27	7/27	7/27	7/27	7/28	7/29
Day	Mon	Mon	Mon	Mon	Mon	Mon	Tues	Tues	Tues	Tues	Tues	Tues	Wed	Wed	Wed	Wed	Wed	Wed	Thur	Fri
Time	10am	11am	noon	1pm	2pm	4pm	10am	11am	noon	1pm	2pm	4pm	10am	11am	noon	1pm	2pm	4pm	10am	10am
Time After Shock,hrs	0	1	2	3	4	6	24/0	1	2	3	4	6	24/0	1	2	3	4	6	24	48
COD-Total	32	28	36	48	48		24	24	28	32	40	28	20	24	32	32	36	36	20	32
Suspended Solids	2	0	0	2	2	2	9.5	10	11.3	48	16	19	16	12	2	2	11	16	13	18
NO_3-N	10.2		11.8		12.4		9.3		9.9		10.6		11.2		10.2		10.5		8.4	8.4
pH	7.1	7.2	7.2	7.1	7.1	7.1	7.3	7.4	7.2	7.1	7.1							7.1		

Phase	Shock						IIIB Shock						Shock							
Date	8/1	8/1	8/1	8/1	8/1	8/1	8/2	8/2	8/2	8/2	8/2	8/2	8/3	8/3	8/3	8/3	8/3	8/3	8/4	8/5
Day	Mon	Mon	Mon	Mon	Mon	Mon	Tues	Tues	Tues	Tues	Tues	Tues	Wed	Wed	Wed	Wed	Wed	Wed	Thur	Fri
Time	10am	11am	noon	1pm	2pm	4pm	10am	11am	noon	1pm	2pm	4pm	10am	11am	noon	1pm	2pm	4pm	10am	10am
Time After Shock, hrs	0	1	2	3	4	6	24/0	1	2	3	4	6	24/0	1	2	3	4	6	24	48
COD-Total	36	91	253	269	249	170	44	48	76	84	80	68	20	16	32	32	56	28	16	36
Suspended Solids	7	32	130	136	104	72	9	4	3	23	3	12	3	3	1	7	9	9	16	28
NO_3-N	6.4		7.6		5.6		0		0		0		0		0		0		0.1	2.0
pH	7.3	7.2	7.2	7.0	7.1	7.1	7.3	7.3	7.3	7.3	7.3	7.1	7.3	7.3	7.2	7.2	7.2	7.3	7.3	7.2

TABLE N-4

UNIVERSITY OF LOWELL PILOT PLANT - OPERATION IN EXTENDED AERATION MODE - PHASE III

DISSOLVED OXYGEN (mg/l)



Phase	IIIA																			
	Shock						Shock						Shock							
Date	7/25	7/25	7/25	7/25	7/25	7/25	7/26	7/26	7/26	7/26	7/26	7/26	7/27	7/27	7/27	7/27	7/27	7/27	7/28	7/29
Day	Mon	Mon	Mon	Mon	Mon	Mon	Tues	Tues	Tues	Tues	Tues	Tues	Wed	Wed	Wed	Wed	Wed	Wed	Thur	Fri
Time	10am	11am	noon	1pm	2pm	4pm	10am	11am	noon	1pm	2pm	4pm	10am	11am	noon	1pm	2pm	4pm	10am	10am
Time After Shock, hrs	0	1	2	3	4	6	24/0	1	2	3	4	6	24/0	1	2	3	4	6	24	48
Point 1A	7.7	4.8	6.0	7.0	7.2	7.1	7.7	5.2	6.7	7.1	7.0	7.4	8.0	5.3	6.5	6.5	6.7	6.5	7.5	7.8
1B	7.5	4.5	5.6	6.8	6.9	6.7	7.5	4.7	6.2	6.9	6.7	6.9	7.8	5.2	6.4	6.3	6.5	6.3	7.3	7.7
2A	6.2	2.2	4.0	5.9	6.1	6.1	5.9	1.1	3.3	5.4	5.3	5.1	6.4	1.2	4.4	4.7	4.8	5.0	5.4	6.1
2B	6.1	2.1	3.9	5.9	6.1	6.0	5.8	0.9	3.3	5.3	5.2	5.1	6.3	1.0	4.4	4.7	4.7	5.0	5.3	6.0
3A	6.0	1.9	3.8	5.8	6.0	5.9	5.8	0.8	3.2	5.3	5.2	4.9	6.1	0.8	4.3	4.5	4.6	4.9	5.2	5.9
3B	6.0	2.0	3.8	5.8	5.9	5.9	5.7	0.7	3.2	5.3	5.1	4.8	6.1	0.7	4.3	4.5	4.6	4.9	5.2	5.9
4A	6.0	4.6	3.6	4.0	4.4	4.8	6.2	5.1	4.7	4.8	4.7	5.0	6.2	5.3	4.4	4.1	4.2	4.1	5.2	6.5

Phase	IIIB																			
	Shock						Shock						Shock							
Date	8/1	8/1	8/1	8/1	8/1	8/1	8/2	8/2	8/2	8/2	8/2	8/2	8/3	8/3	8/3	8/3	8/3	8/3	8/4	8/5
Day	Mon	Mon	Mon	Mon	Mon	Mon	Tues	Tues	Tues	Tues	Tues	Tues	Wed	Wed	Wed	Wed	Wed	Wed	Thur	Fri
Time	10am	11am	noon	1pm	2pm	4pm	10am	11am	noon	1pm	2pm	4pm	10am	11am	noon	1pm	2pm	4pm	10am	10am
Time After Shock,hrs	0	1	2	3	4	6	24/0	1	2	3	4	6	24/0	1	2	3	4	6	24	48
Point 1A	7.6	5.7	5.5	5.7	5.5	5.1	7.1	5.0	5.4	5.9	5.9	5.9	6.9	3.7	4.6	5.2	5.7	5.7	6.5	6.6
1B	7.4	5.5	5.4	5.5	5.3	4.8	6.9	4.7	5.1	5.5	5.6	5.6	6.6	3.5	4.5	5.0	5.4	5.4	6.2	6.5
2A	5.5	2.1	2.6	3.3	3.6	2.7	5.7	0.8	2.1	3.1	3.3	3.3	4.5	0.5	1.4	2.6	3.4	3.4	4.6	4.0
2B	5.5	2.1	2.6	3.3	3.5	2.7	5.5	0.8	2.1	3.1	3.2	3.3	4.5	0.5	1.4	2.6	3.4	3.3	4.5	3.9
3A	5.4	1.9	2.5	3.3	3.5	2.4	5.3	0.7	2.0	2.8	3.1	3.2	4.3	0.3	1.2	2.4	3.2	3.2	4.5	3.8
3B	5.3	1.8	2.5	3.3	3.4	2.4	5.1	0.7	1.9	2.8	3.1	3.2	4.0	0.4	1.1	2.4	3.2	3.2	4.4	3.8
4A	6.5	5.0	3.9	3.3	2.8	2.0	3.8	3.2	2.5	2.3	2.3	2.3	4.4	2.8	1.6	1.7	2.0	2.8	3.9	4.3

TABLE N-5

UNIVERSITY OF LOWELL PILOT PLANT - OPERATION IN EXTENDED AERATION MODE - PHASE III

MIXED LIQUOR (mg/l)

Phase	Shock						IIIA Shock						Shock							
Date	7/25	7/25	7/25	7/25	7/25	7/25	7/26	7/26	7/26	7/26	7/26	7/26	7/27	7/27	7/27	7/27	7/27	7/27	7/28	7/29
Day	Mon	Mon	Mon	Mon	Mon	Mon	Tues	Tues	Tues	Tues	Tues	Tues	Wed	Wed	Wed	Wed	Wed	Wed	Thur	Fri
Time	10am	11am	noon	1pm	2pm	4pm	10am	11am	noon	1pm	2pm	4pm	10am	11am	noon	1pm	2pm	4pm	10am	10am
Time After Shock, hrs	0	1	2	3	4	6	24/0	1	2	3	4	6	24/0	1	2	3	4	6	24	48
Suspended Solids	2750						3170						3140						3180	3190
Volatile Susp. Solids	2050						2770						2560						2220	2300
pH											7.4						7.6	7.1	7.9	
Temperature, °C	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
D.O.Uptake mg/l-hr-gm	2.0	5.1	3.3	3.1	5.1	5.0	1.9	2.9	2.8	2.8	3.0	2.7	1.4	3.2	2.4	2.7	3.8	3.5	1.9	2.6
Settlometer																				
5 minutes	500	500	510	500	540	490	610	550	580	630		520	610	600	550	620	810	640	690	640
10 minutes	390	400	400	400	420	380	470	420	440	480	470	400	465	470	440	480	630	490	530	490
15 minutes	340	350	350	350	360	340	410	360	380	410	400	350	400	400	390	410	510	410	440	420
20 minutes	300	310	310	310	330	300	360	330	340	370	350	320	360	360	350	370	440	370	390	370
25 minutes	280	290	290	290	300		330	300	310	340	330	300	330	330	330	340	390	350	350	340
30 minutes	270	280	270	270	290	270	310	290	300	310	310	290	300	300	310	320	360	330	330	320
45 minutes	240	250	240	250	260	250	275	270	270	280	280	270	280	280	280	300	310	300	290	280
60 minutes	230	320	240	240	250	250	250	250	250	260	260	260	250	260	260	280	280	280	280	260

(continued)

TABLE N-5 (continued)

Phase	Shock						Shock	IIIB					Shock							
Date	8/1	8/1	8/1	8/1	8/1	8/1	8/2	8/2	8/2	8/2	8/2	8/2	8/3	8/3	8/3	8/3	8/3	8/3	8/4	8/5
Day	Mon	Mon	Mon	Mon	Mon	Mon	Tues	Tues	Tues	Tues	Tues	Tues	Wed	Wed	Wed	Wed	Wed	Wed	Thur	Fri
Time	10am	11am	noon	1pm	2pm	4pm	10am	11am	noon	1pm	2pm	4pm	10am	11am	noon	1pm	2pm	4pm	10am	10am
Time After Shock, hrs	0	1	2	3	4	6	24/0	1	2	3	4	6	24/0	1	2	3	4	6	24	48
Suspended Solids	2800						3140						3660						3780	3810
Volatile Susp. Solids	2190						2510						2880						2860	2920
pH	7.0	7.8	7.6	7.5	7.6	7.6	7.3	8.0	7.9	8.1	8.0	7.7	7.2	7.8	7.6	7.8	7.7	7.6	8.0	7.8
Temperature, °C	23						23						24						24	24
D.O.Uptake mg/l-hr-gm	1.7	3.8	4.4	4.7	4.9	5.3	3.6	4.8	4.6		4.2	3.9	2.9	4.2	4.7	4.2	4.2	3.6	2.9	2.9
Settlometer																				
5 minutes	520	580	590	650	660	630	670	590	670	660	660	600	740	790	690	690	780	730	850	820
10 minutes	410	450	460	500	500	480	510	460	510	510	500	460	570	630	530	530	600	560	710	660
15 minutes	350	390	390	430	440	410	430	400	440	440	420	400	480	530	460	460	500	470	590	550
20 minutes	320	350	360	380	390	370	390	370	400	400	380	370	430	460	420	420	450	420	510	490
25 minutes	290	330	330	350		340	360	350	370	370	350	340	400	420	390	390	410	390		440
30 minutes	280	300	300	320	320	320	340		340	350	330	330	380	390	370	370	390	370	430	410
45 minutes	250	270	270	290	290	280	310	300	300	320	300	300	340	350	340	340	350	340	370	360
60 minutes	230	250	250	260	270	260	290	280	290	300	280	290	320	320	320	320	320	320	340	340